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Perceptual and Acoustic Implications of Electric Powered Two-wheelers in Urban Environment

Dimitris Margaritis[1], Aikaterini Touliou[1], Evangelos Bekiaris[1], Haibo Chen[2]

[1] Hellenic Institute of Transport (HIT), Centre for Research and Technology Hellas (CERTH), 6th km Harilaou Thermi Road, 57001 Thermi, Thessaloniki, Greece
[2] Institute for Transport Studies, Faculty of Environment, University of Leeds, 34–40 University Road, LS2 9JT Leeds, UK
* Corresponding author, e-mail: dmarg@certh.gr

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Abstract

The increasing adoption of electric Powered Two-Wheelers (e-scooters and e-motorcycles) in urban mobility has introduced a new safety challenge: their low noise emissions. While reduced acoustic pollution is environmentally advantageous, it may impair the auditory detectability of such vehicles by vulnerable road users, such as pedestrians and cyclists. This study aimed to investigate both the noise characteristics and perceptual detectability of electric versus conventional internal combustion engine (ICE) scooters under simulated urban conditions. Noise measurements were taken for two scooters – one electric and one ICE-powered – at three speeds (10, 20, and 30 km/h). Sixteen participants then completed a perception experiment in which they were asked to detect the passing vehicles while visual cues were blocked. Results showed that the electric scooter consistently emitted approximately 8 dB(A) less noise across all speeds. Critically, only 31% of participants failed to detect the ICE scooter, whereas 69% did not perceive the electric scooter. Reaction times were shorter for the electric vehicle when it was detected, but detection occurred at a dangerously close distance (mean ≈ 1.5 m). The findings underscore the need for revised safety regulations and perceptual enhancements for low-noise vehicles. As electric two-wheelers become more prevalent, understanding their impact on pedestrian safety is essential for designing effective urban transportation policies.

Keywords

electric scooters, pedestrian safety, auditory perception, noise emissions, urban mobility

1 Introduction

The global transportation landscape is undergoing a profound transformation, driven by the increasing demand for sustainable mobility solutions and rapid technological advancement (Danilevičius et al., 2025; Ugnenko et al., 2019). Among the most significant developments is the rise of electric vehicles (EVs), including electric two-wheelers such as e-scooters and e-motorcycles. These vehicles offer a cleaner, quieter, and more energy-efficient alternative to traditional internal combustion engine (ICE) vehicles, particularly in congested urban environments (Velasquez and Eisenbeiss, 2015; Weinert et al., 2008). Their compact design, zero tailpipe emissions, and operational cost advantages have made electric scooters a favored option for personal mobility and last-mile transportation.

However, alongside these benefits, electric vehicles introduce a new set of safety concerns, particularly related to their low acoustic emissions. While ICE vehicles emit noticeable engine and exhaust noise, which serves as a passive warning signal to pedestrians and cyclists, electric two-wheelers are notoriously quiet, especially at low speeds (Robart and Rosenblum, 2009; Walton et al., 2022). In dense urban environments, where auditory cues are often critical for non-visual hazard detection, this reduced noise signature can pose serious risks – especially to vulnerable road users such as children, the elderly, individuals with visual impairments, and distracted pedestrians (JASIC, 2009; Ulrich et al., 2014; Verheijen and Jabben, 2010).

The challenge becomes particularly acute in cities where visual obstructions, such as parked vehicles or infrastructure, limit a pedestrian's ability to see oncoming traffic. In such settings, hearing a vehicle becomes a primary mechanism of detection. Research has shown that pedestrians typically require a sound to be at least 2 dB(A) above background noise to reliably detect an approaching vehicle (Goodes et al., 2009). Electric scooters, however, often fail to exceed this threshold at urban speeds under

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30 km/h, raising significant safety concerns. This risk is compounded by studies indicating delays in pedestrian reaction time and shortened detection distances for electric vehicles compared to ICE vehicles (Wogalter et al., 2001).

While many studies have explored the acoustic profiles and detectability of electric cars (e.g., Konet et al., 2011; Patil and Khairnar, 2021), research on electric two-wheelers remains limited. This is a notable gap, given the unique dynamics and usage patterns of two-wheeled vehicles. Unlike cars, motorcycles and scooters often operate in closer proximity to pedestrians and have narrower wheelbases, lighter frames, and differing acceleration profiles – all of which influence their acoustic behavior and perceptibility.

Existing research has suggested that most EV-related pedestrian accidents occur at low speeds and in non-forward motion scenarios, such as reversing or exiting parking spaces (NHTSA, 2017). However, the extent to which low noise levels contribute directly to these incidents remains inconclusive due to limited post-crash data and inconsistent accident reporting frameworks. Nonetheless, experimental studies indicate that pedestrians detect EVs later and with greater difficulty than ICE vehicles under realistic traffic conditions (Konet et al, 2011; Patil and Khairnar, 2021).

Against this backdrop, the present study aims to explore the relationship between noise emissions and perceptual detection of electric versus ICE-powered two-wheelers under conditions that simulate the urban acoustic environment. Specifically, the study investigates:

1. whether electric scooters emit lower noise levels than conventional ICE scooters at varying speeds;
2. whether these differences translate into perceptual delays or failures in pedestrian detection of the approaching vehicle.

2 Methods

2.1 Participants

A total of 16 individuals were recruited to participate in the experimental study. Participants were selected based on shared demographic and experiential characteristics to ensure a homogeneous sample, thereby minimizing inter-individual variability in perceptual and behavioral responses. The determination of sample size was guided by established methodological standards for ensuring adequate statistical power in behavioral research, in accordance with Cohen's (1988) recommendations. Prior to participation, each individual completed a standardized demographic and background information form, which captured relevant personal and experiential data. A detailed overview of the sample characteristics is provided in Table 1.

Table 1 Sample characteristics

Category/Gender	Men	Women
Number of participants	7	9
Age (Years)	Mean: 28.3 (Range: 23–33)	Mean: 33.9 (Range: 24–41)
Education	Post secondary, 100%	Post secondary, 100%
Years since acquiring driver's license	Mean: 8.4 (Range: 4–11)	Mean: 10.6 (Range: 0–21)
Number of minor accidents in the past 3 years	Mean: 0.6 (Range: 0–1)	Mean: 0.4 (Range: 0–2)
How often do you drive?		
Daily	72%	78%
2–3 times per week	14%	–
Once a week	–	–
Rarely	14%	22%
How often do you walk?		
Daily	100%	67%
2–3 times per week	–	11%
Once a week	–	11%
Rarely	–	11%
You usually walk for (multiple answers allowed):		
Recreation	71%	55%
To go to work	71%	–
Shopping	14%	67%
To reach a transit stop	43%	22%
Approximately how many kilometers did you drive last year?		
Less than 5,000–10,000 km	43%	44%
10,000–15,000 km	57%	44%
15,000–20,000 km	–	–
Over 20,000 km	–	12%
In the past 3 years, have you received a fine for:		
Speeding	29%	0%
Reckless driving	14%	0%
Driving under the influence (alcohol or drugs)	29%	0%
Do you have difficulty hearing in your daily activities?	0%	0%
Have you been exposed to high-intensity noise?	43%	22%
Do you have difficulty hearing a whisper?	29%	11%
Do you have difficulty hearing passing cars?	0%	0%
Do you have difficulty hearing passing motorcycles?	0%	11%

2.2 Experimental equipment

The experimental setup incorporated a combination of hardware and software components, some of which were repurposed from prior research activities, while others were specifically developed for the purposes of this study. All costs associated with custom-built tools or additional equipment were covered by the authors. In several cases, voluntary contributions from collaborators – either through the donation of personal items or technical assistance – facilitated the execution of the experimental design.

Two scooter-type vehicles were employed: one gasoline-powered and one electric. The Honda Dylan 125, a conventional scooter with a combustion engine, had a mileage of 4,350 km and was bored in mechanically sound condition. The second vehicle, the EVT 4000-e, was an electric scooter owned by the Hellenic Institute of Transport and had been driven for approximately 1,500 km. Both vehicles were comparable in terms of mechanical characteristics and were deemed suitable for the controlled comparative analysis central to this study.

Acoustic measurements were obtained using the METREL FONS sound level meter, a device calibrated by the manufacturer and compliant with international standards IEC 61672-1:2013 (IEC, 2013) and IEC 61260-1:2014 (IEC, 2014). This instrument supports both real-time and logger-based data acquisition modes and is capable of recording a comprehensive range of acoustic parameters, including time-weighted levels, equivalent continuous levels, peak levels, and percentile sound pressure levels.

To accurately record the time of vehicle passage, two pairs of infrared (IR) emitter-receiver sensors were positioned at designated start and end points along the test track. These sensors were integrated into a custom-modified computer mouse circuit such that the interruption of the IR beam by a passing vehicle triggered an electronic signal equivalent to a mouse button press. This setup allowed for precise time logging corresponding to the vehicle's entry and exit from the measurement zone.

A custom Java-based software tool (Ecma International, 2023) was developed to log the timestamps associated with each IR-triggered mouse event. The software automatically generated time-stamped text files containing the activation time, date, and type of input, thereby ensuring accurate and organized data storage for each test session.

Divided attention was assessed using a dichotomous testing paradigm, wherein participants were required to simultaneously monitor and respond to two distinct types of stimuli. The assessment tool employed in this study evaluates divided attention by measuring the individual's ability to discriminate between visual (e.g., detection of a square among crosses) and auditory (e.g., detection of irregularities within a sequence of tones) stimuli. To minimize the potential for stimulus sequence learning – an effect that could arise from repeated, systematic exposure – participants were presented with varied stimulus sequences across trials. This ensured that responses reflected genuine perceptual discrimination rather than anticipatory learning. The total number of trials was set at 100 for the visual task and 200 for the auditory task. For the purposes of the present study, only the auditory component was administered. The tool, known as WinTAP (Centre for Research and Technology Hellas, 2004), was developed as part of the European Union–funded research project "SENSATION".

Additional equipment used in the experimental procedure included a laptop computer for data control and logging, and a standard computer mouse, which participants held during perception testing to register detection responses. A wooden panel, measuring 112 cm by 456 cm, was installed to obstruct participants' visual access to approaching vehicles, thereby enforcing reliance on auditory cues. Finally, a subjective evaluation scale, presented in the form of a structured questionnaire, was administered to assess perceived sound salience and perceived risk. This instrument was developed in collaboration with a licensed psychologist experienced in behavioral assessment methodologies.

2.3 Experimental design

The experimental protocol was divided into two primary phases. The first phase focused on the quantification of noise emissions produced by each two-wheeled vehicle. The second phase aimed to measure the perceptual differences in detecting electric versus conventionally powered scooters.

During the noise identification phase, measurements were conducted using two scooters under identical environmental conditions. Each vehicle was tested at three distinct speeds – 10, 20, and 30 km/h – employing the standardized pass-by method to ensure consistency and comparability of acoustic output.

The second phase assessed auditory perception using a within-subjects design, wherein each participant was exposed to both types of vehicles. This approach allowed for intra-individual comparison, minimizing variability due to individual differences. The order of vehicle presentation was randomized for each trial to eliminate any potential order effects, which could bias results if participants anticipated the vehicle type. Familiarity with the sequence might otherwise lead participants to allocate more attention to the vehicle perceived as harder to detect (e.g., electric *vs*. conventional).

In this design, the independent variable (IV) was the type of scooter – implicitly, the type and intensity of the sound it emitted. The dependent variable (DV) was the time of auditory detection. As per experimental conventions, the dependent variable represents the measure expected to vary in response to changes in the independent variable. Additionally, perceptual detection time was compared with reaction times collected during the divided attention test using WinTAP software (Sensation, 2004), providing a potential cognitive correlate to real-world detection times.

Vehicle speed for the perception tests was standardized at 25 km/h, as lower speeds (e.g., 10–15 km/h) commonly cited in literature were deemed unrepresentative of typical urban scooter movement. Visual occlusion was implemented using a vertically positioned wooden panel, preventing participants from seeing the approaching scooter. This setup simulated real-world urban conditions where the pedestrian's visual field may be obstructed by parked vehicles or architectural structures. Eye masking was deliberately avoided to eliminate the need for an adaptation phase, which could vary significantly among individuals and introduce unwanted variability or participant discomfort. All tests were conducted in daylight, avoiding artificial enhancement of sensory reliance (e.g., heightened auditory sensitivity in the dark).

2.4 Experimental procedure

The full experimental protocol was executed in three distinct stages, each conducted on a separate day to reduce participant fatigue and cross-task interference. The stages included:

1. the divided attention assessment;
2. vehicle noise level measurements;
3. the real-world perception tests with human participants.

Prior to participation, all individuals were confirmed to be in good physical condition, a prerequisite for ensuring the reliability of reaction time data. Each participant received a brief general explanation of the study's purpose, although specific hypotheses were not disclosed, thereby preventing cognitive bias during the perception tasks. In line with ethical research guidelines, verbal informed consent was obtained from all participants, particularly due to the collection of personal and reaction-based data.

The divided attention tests were conducted in a quiet indoor setting, with only the participant and the experimenter present. Each session lasted approximately 10 min and consisted of 200 auditory trials, generated by the WinTAP software (Sensation, 2004). Participants were instructed to press a key upon detecting an anomaly in the tone sequence. Missed or premature responses were recorded as errors and documented in the output text files. A total of 16 unique data files were generated, corresponding to the number of participants.

The second phase was conducted in a real-world test environment, specifically a paved road segment in front of the Hellenic Institute of Transport in Thessaloniki. This location was selected based on the following criteria:

- The surface was smooth and of high-quality asphalt, suitable for controlled pass-by trials.
- The presence of adjacent vehicle traffic allowed simulation of realistic urban auditory environments. The adjacent road featured one lane per direction and a speed limit of 50 km/h – conditions typical of urban roads with heightened risk for vulnerable road users.
- The area was secure and enclosed, minimizing safety concerns and ensuring controlled access.
- Buildings and parked cars along the road provided realistic visual obstructions, simulating pedestrians' limited visual fields in urban settings.
- The location allowed for easy transportation and setup of equipment, including access to electrical power for operating the instruments.
- The site enabled scheduled coordination of all 16 participants, avoiding overlapping trials and ensuring that no participant observed prior runs.
- Background noise levels at the test site closely resembled those measured on typical single-lane roads in Thessaloniki. Preliminary noise measurements were collected from Papanastasiou and Martiou Streets at pedestrian average ear height (1.5 m) during peak and off-peak hours on different weekdays. These were then compared to baseline readings from the test site under similar environmental conditions (16–18 °C, light wind). Results confirmed the acoustic comparability of the chosen location with actual city streets, aligning with values reported by Yamauchi et al. (2010).

All perception tests were completed on the same day to ensure uniform environmental conditions across participants. Ambient temperature during testing was 18 °C with minimal wind. Both scooters were operated by a single, highly experienced rider (>20 years), selected to ensure consistency in speed and handling, particularly critical when operating at low speeds over the short test distance (approximately 70–80 m).

Preparation of the test site required approximately 90 min and included:

- The parallel parking of three passenger vehicles along the direction of scooter movement to simulate urban congestion.
- Installation of two IR emitter-receiver pairs at a 50-m distance. The first pair marked the test's start, and the second marked its end. Both pairs were connected to a laptop *via* a custom mouse interface using identical-length cables (33 m) to maintain consistent electrical resistance.
- The sound level meter was positioned 4 m before the test endpoint and 4 m laterally from the center of the road, elevated 1.5 m above ground to match ear height. It was time-synchronized with the laptop to align acoustic and timing data. Sampling frequency was set to the device's maximum: one recording every 2 s.
- A wooden panel was positioned 2 m from the center of the road and 1 m beyond the endpoint to prevent angular visual contact with the scooter during the test's final moments.

The acoustic measurements were carried out in a quiet, unobstructed area in proximity to the primary test site. The sound level meter was again placed 4 m from the vehicle trajectory and mounted on a tripod at a height of 1.5 m. The experimenter paused data acquisition once the scooter had passed 10 m beyond the meter. All measurements were performed by the same operator and were repeated twice for reliability. Ambient temperature during this phase was 17 °C, with negligible wind, and measurements began at 09:45 AM. A 2-min background noise sample was also recorded before vehicle measurements commenced. Results from this phase, including average noise levels for both scooters, are presented in Table 2.

Table 2 Noise measurements of ICE and electric scooters

		10 km/h		20 km/h		30 km/h	
	Place noise	ICE sc.	e-sc.	ICE sc.	e-sc.	ICE sc.	e-sc.
LAF (db(A))	48.2	64.5	50.2	64.6	52.8	68.0	55.9
LAeq (db(A))	48.2	57.6	49.4	59.3	50.3	60.3	51.3
LAF max (db(A))	52.0	68.9	52.6	71.4	53.8	72.8	56.1
LAF min (db(A))	47.5	50.7	48.6	49.8	49.3	49.7	49.1
LApeak (db(A))	72.3	81.8	79.7	85.9	68.2	84.7	67.8

2.5 Data processing and statistical analysis

Raw data from the experimental stages were processed as follows: noise level data were extracted from targeted 10-s intervals corresponding to each test event. Reaction times were computed based on the precise timestamps generated by the infrared sensor system. Vehicle speeds were derived from the known test distance (50 m) divided by the measured travel time. Statistical analysis was performed using SPSS version 18.0 (SPSS Inc., 2009). Due to violations of normality assumptions, non-parametric statistical methods were applied, specifically the Wilcoxon signed-rank test for repeated measures. The level of statistical significance was set at $\alpha = 0.05$.

3 Results

The results are organized into three distinct subsections:

1. findings from the subjective rating scales (questionnaire responses);
2. noise level measurements;
3. outcomes of the perception experiments.

3.1 Subjective questionnaire results

The subjective assessment results, derived from participant-completed questionnaires, reveal notable gender-based perceptual differences. As illustrated in Table 3, a majority of male participants (86%) reported that two-wheeled vehicles are more easily detectable acoustically compared to passenger cars. While a considerable proportion of female participants (55%) shared this view, their responses were markedly less frequent than those of the male participants.

A particularly noteworthy finding emerged regarding participants' views on accident risk based on auditory detectability. A significant portion of male participants (71%) considered motorcycles more dangerous than cars in situations where the vehicle could not be heard, whereas female participants (55%) expressed the opposite belief, identifying cars as posing a greater risk under the same conditions.

Following the completion of the experimental trials, all 16 participants were asked to complete a brief post-experiment questionnaire. 15 out of 16 participants reported not hearing the electric scooter as it passed. Surprisingly, 6 individuals also indicated that they did not hear the conventional

Table 3 Subjective perception of risk – Questionnaire results

Question	Response	Men	Women
What do you hear more clearly?	Car	14%	44%
	PTW	86%	56%
Which vehicle is more dangerous if not heard approaching?	Car	29%	55%
	PTW	71%	45%

scooter either. An overwhelming majority (94%) of participants rated the passage of the electric scooter as highly dangerous, citing a lack of clear auditory cues. Notably, only one participant in the entire study reported not feeling at risk during either experimental condition.

3.2 Noise measurement results

For the conventional scooter, LAeq values increase gradually with speed, starting at approximately 58 dB(A) at 10 km/h and reaching around 61 dB(A) at 30 km/h. Correspondingly, LAFmax values range from approximately 68 dB(A) to 72 dB(A) across the same speed interval. The electric scooter, by contrast, consistently generates lower noise emissions. Its LAeq values rise modestly from around 49 dB(A) at 10 km/h to approximately 51 dB(A) at 30 km/h, while its LAFmax readings increase from about 53 dB(A) to 56.5 dB(A).

When comparing the two vehicles, the conventional scooter is significantly louder across all speed levels in both LAeq and LAFmax measurements. The gap is especially notable in the LAFmax values, where the conventional scooter exceeds the electric scooter by roughly 12 to 15 dB(A), depending on speed.

3.3 Perception experiment results

In the conventional scooter trial, 5 of the 16 participants failed to detect the vehicle auditorily. Among those who did perceive it, the mean reaction time was 0.767 s (standard deviation: 0.904 s; standard error: 0.273 s). In contrast, during the electric scooter trial, 11 of the 16 participants failed to perceive the vehicle. For the 5 participants who did detect it, the mean reaction time was 0.195 s (standard deviation: 0.365 s; standard error: 0.163 s). A comparison between the number of participants who perceived the scooters versus those who did not revealed a statistically significant difference in favor of lower detectability for the electric scooter (Chi-square test: $\chi^2 = 4.5$, p = 0.034). However, when comparing reaction times among only those participants who successfully detected the vehicles, the difference between the two conditions was not statistically significant (Wilcoxon signed-rank test: $p = 0.080$). Table 4 presents non-significant correlations between various measured and self-reported parameters, highlighting that no meaningful statistical relationships were observed among these variables.

Table 4 Non-significant correlations between variables

Parameter 1	Parameter 2	p-value (ρ)
Reaction time	*LAeq (noise level)*	0.370
Detection of vehicle	*"I hear more easily" (self-report)*	0.227

4 Discussion

The findings of this study provide important insight into the acoustic behavior and perceptual detectability of electric versus conventionally powered two-wheeled vehicles in an urban context. Noise level measurements (LAeq) clearly demonstrated that the electric scooter consistently emitted approximately 8 dB(A) less noise than its gasoline-powered counterpart across all tested speeds (10, 20, and 30 km/h). This difference was independent of the operating speed and aligns with previous research indicating that electric vehicles generally produce lower operational noise due to the absence of engine combustion and reduced mechanical complexity (Poveda-Martínez et al., 2017a; Sheng et al., 2016).

The reduction in noise output had a direct impact on perceptual detection rates among pedestrians (Fleury et al., 2016; Poveda-Martínez et al., 2017a; 2017b). Statistical analysis revealed a significantly lower rate of detection for the electric scooter compared to the conventional one ($\chi^2 = 4.5$, $p = 0.034$). Specifically, 31% of participants failed to detect the gasoline-powered scooter, whereas 69% did not perceive the electric scooter. This perceptual gap is critical in safety contexts, as a vehicle's detectability is closely tied to pedestrian response times and accident avoidance potential (JASIC, 2009). Furthermore, participants' subjective sense of safety was inversely related to detectability. While 44% of participants described the passage of the conventional scooter as a hazardous traffic event, the percentage rose to 94% for the electric scooter, indicating a heightened perception of danger in the absence of clear auditory cues.

Noise level trends across speeds showed a linear increase in both vehicle types, consistent with expectations, as greater speed typically increases both engine and tire noise (Sandberg and Ejsmont, 2002). However, the electric scooter's noise levels remained nearly constant between 10 and 20 km/h, reflecting the limited variability in motor-generated noise at low speeds. This observation corroborates findings by Emadi et al. (2005), who noted that electric drivetrains exhibit minimal acoustic variation below moderate speeds.

When comparing the magnitude of acoustic differences between electric and gasoline-powered scooters, interesting patterns emerge. Previous literature reports a noise difference of 10–15 dB(A) between electric and combustion engine PTW (Lelong et al., 2014). In this study, the 8 dB(A) difference observed remained consistent up to 30 km/h, likely due to scooters' lower rolling resistance – attributable to their reduced weight, smaller contact patch, and two-wheel configuration. Future research could expand the speed range to determine if this gap persists at higher velocities. However, a practical limitation exists, as most electric scooters are engineered for top speeds between 40–50 km/h, often regulated by legal restrictions, requiring extended track lengths for stable testing.

Out of the 32 total perception experiments conducted, scooters went undetected in 16 trials. This can be attributed to low-noise engine design and increasingly stringent noise regulations for exhaust systems. In urban settings, where background noise averages 2–4.5 dB(A) higher than the scooter's emissions, the electric vehicle often remained inaudible or was detected very late, as reflected in the mean reaction time of 0.195 s. Based on the data, the average detection distance was approximately 1.5 m, a proximity that understandably generated a strong sense of insecurity among participants. Literature suggests that a vehicle must emit noise at least 2 dB(A) above ambient levels to be reliably detected in urban environments (Goodes et al., 2009), a condition often unmet by electric scooters in this study.

The non-significant statistical results observed in parameter correlation analyses are likely due to the limited sample size (N = 16) and the number of zero reaction time values, which skewed the distribution. This issue could be addressed either by increasing the sample size or by implementing repeated trials per subject, to allow for within-subject analysis and improved statistical robustness (Field, 2013).

Participant beliefs also provided valuable context. Notably, 71% of respondents stated they perceive motorcycles as more audible than cars, a belief possibly shaped by exposure to motorcycles with illegal or modified exhaust systems, often stripped of mufflers or air filters. While such modifications were once culturally prevalent, there has been a societal shift toward viewing motorcycles as utilitarian rather than performative or symbolic objects, especially in urban mobility contexts (Will et al., 2021).

Cross-referencing the current study's noise measurements with those of typical passenger cars, it appears that at speeds above 20 km/h, the internal combustion scooter is quieter than conventional cars, supporting the idea that urban two-wheelers may emit less noise than expected when compared to four-wheeled vehicles.

Finally, participants' perception that motorcycles are more dangerous if not heard aligns with vehicle dynamics. As single-track vehicles, scooters lack the stability and maneuvering margin of four-wheeled vehicles, making evasive maneuvers or sudden braking more difficult to perform safely. This mechanical reality underscores the importance of auditory awareness as a critical safety cue for vulnerable road users such as pedestrians (Robart and Rosenblum, 2009).

5 Conclusions

The present study focused specifically on the noise characteristics and perceptual detectability of electric two-wheeled vehicles, such as scooters, compared to their conventionally powered counterparts. While several previous studies have examined acoustic differences between electric and internal combustion engine (ICE) passenger cars, research on two-wheeled EVs remains limited. To address this gap, we conducted controlled field experiments involving 16 participants under urban-simulated acoustic conditions and constant vehicle speeds (25 km/h).

The first hypothesis, that electric scooters generate lower noise levels than ICE-powered scooters, was supported across all measured speeds (10, 20, and 30 km/h). On average, electric scooters produced approximately 8 dB(A) less noise, a difference consistent with findings in related literature and sufficient to affect perceptual awareness. The second hypothesis, that electric scooters would be detected less frequently or more slowly than conventional ones, was also confirmed. While 69% of participants failed to detect the electric scooter, only 31% failed to perceive the conventional model under the same conditions.

Noise measurements confirmed a modest linear increase in sound levels with speed for both vehicle types, which aligns with expectations based on engine and tire interaction with the road surface. However, the sound levels for electric scooters remained nearly constant between 10 and 20 km/h, due to the minimal variation in motor noise at low speeds. Compared to passenger cars, the difference in detectability at low speeds (e.g., 10–15 km/h) appears comparable between vehicle types, but the noise advantage of electric two-wheelers persists even as speed increases, likely due to their reduced rolling resistance and lighter frame.

These findings have important safety implications. The auditory detection distance for electric scooters averaged just 1.5 m, leaving minimal time for pedestrians to react – especially in busy urban environments. Nearly all participants rated the electric scooter's passage as unsafe, underscoring the psychological effect of inaudibility. While new-generation ICE scooters may also go undetected due to stricter noise regulations and advanced muffler systems, the problem is amplified in electric models.

Based on the experimental findings, the following conclusions can be drawn:

- Electric scooters are perceived as less detectable and more dangerous than ICE scooters by pedestrians in urban environments.
- Despite technological advancements, new ICE scooters can also fail to be perceived, especially under conditions of background noise or when operating quietly.
- The majority of participants associated the electric scooter's passage with a perceived risk, emphasizing the potential threat posed by inaudible vehicles.
- Further research is essential, particularly in the form of large-scale accident data analysis, to determine the real-world safety impact of low-noise vehicles.

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