Characterisation of Horse Response to Electric Car Noise

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Executive Summary

The aim of this project was to determine if a horse will be able to sense (hear) the approach of a vehicle much before its rider and is aware of the presence. Therefore, the objectives were to measure noise generated by vehicles using advanced noise sensors followed by application of signal processing methods to characterise noise feature under various experimental conditions.

This was demonstrated with three different horses (Cristina, Julie, Mafin), four vehicles (electric vehicles: Nissan Leaf, SUV, Jaguar, and Petrol/IC-engine car), and three speeds (10 mph, 20 mph, 30 mph) over several trials. Experiments were carried on 25^{th} November 2021 at Dunecht Estate. The car was driven approximately 200 yards, while the climate was cold (around $2^{O}C$) and wind speed was very low. The road condition was rough with patches of wet leaves. Digital mobile camera was used to monitor horse motion and the audacity software was used to record the frequency level through the dodotronic microphone. The observation and data recording were repeatable.

It was concluded that the low-level noises produced by electrical vehicles can be detected by the horses quite early on and they can be aware of the presence of the vehicle much before the humans can. We recommend conducting further experiments in a controlled environment with more vehicles and/or with other conditions in place.

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1. Hypothesis and Aim

The hypothesis of this project was that a horse will be able to sense (hear) the approach of a vehicle much before its rider and is aware of the presence. This is specifically applicable to electric vehicles where the noise levels are low compared to IC engine-based vehicles, rendering them hard to hear by the human riders.

Consequently, the aim of the project is to prove this hypothesis with electric cars generating road noise, using advanced noise sensors and data processing methods.

2. Applicability of the study & Methodology

The methodology was designed to test the above hypothesis. This required that the experiments be performed at a quiet location so that the low noise of an electric vehicle can be heard by the horse.

The methodology is as follows:

1. The electric vehicle was parked at a long enough distance from the location of the horse so that the initial start-up and acceleration will not be heard by it. This distance was assumed and was later proven to be appropriate.
2. The horse was located facing the direction along the road with the car approaching from behind.
3. The noise produced by the car as it approaches the horse was recorded using a high sensitivity microphone with a high frequency band.
4. The reaction of the horse to the car approaching from behind was recorded using a smartphone video camera.
5. The collected data was synchronised and analysed in the frequency and time domains to identify the early indicators of the approach of the car.
6. 3 electric cars of various sizes were selected for the study along with a petrol car. 3 different horses were provided by the British Horse Society (BHS).
7. The vehicle noise was recorded at three speeds (10mph, 20mph, 30mph) with each of the cars.

3. Audio recordings

The audio was recorded at a sampling rate of 176kHz. This meant that any noise that falls within the frequency band of 0-98kHz can be recorded using the microphone. The recording was continued till the car went past the horse. The recorded audio files were then categorised as per the car type, name of the horse, speed of the vehicle and the trial number. The recordings were later analysed using Matlab software to look for frequencies that could characterise the electric vehicle produced noise.

4. Data analysis procedure

The video recordings were first analysed to notice any visual indication from the horse as to the approach of the vehicle. In most cases, there was a distinct reaction where the demeanour changed. A few examples are shown in Table 1. The time point at which this reaction was apparent was noted in each case. In some cases, a distinct reaction could not be seen. Such cases were eliminated from the analysis. It is to be noted that the videos were analysed prior to listening to the audio recordings so as to eliminate any bias on part of the person analysing the data. If the audio files were listened to first, there might be a chance that the person might look for a reaction for the horse at the time point when the electric noise was heard from the audio file. It is also to be noted that the microphone used for the experiments was of high sensitivity, meaning that it not only senses, but also amplifies very low amplitude noises which may not be audible to human ears.

Table 1. Audio and Video record catalogue - Observation times

Sr. No	Car Name	Horse name	Speed	Recording file name	Video file name	Time point
1	SUV	Cristina	10 mph	C-C2S1T1	VID_20211125_112100397	20
2				C-C2S1T2	VID_20211125_112314371	Inconclusive
3				C-C2S1T3	VID_20211125_112455776	23
4			20 mph	C-C2S2T1	VID_20211125_110932748	15
5				C-C2S2T2	VID_20211125_111156523	15
6				C-C2S2T3	VID_20211125_111329175	9
7			30 mph	C-C2S3T1	VID_20211125_111512509	24
8				C-C2S3T2	VID_20211125_111715559	13

As these noises were amplified, they were audible in the recordings. Listening to the audio associated with the video recording made with a smartphone, no noise was heard where an audible noise was present with the high sensitivity microphone. After the video file analysis, the audio files were processed using Matlab. A typical audio record is shown in the figure below:

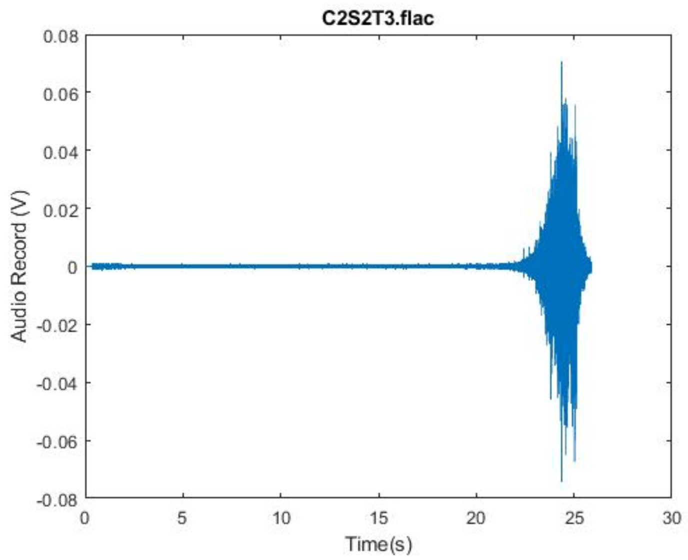

Figure 1 Sample audio record

As seen, the sensor recorded the surrounding noises and on the approach of the vehicle, the recorded signal magnitude increases rapidly and to a high value. From this Fig. 1 it is difficult to identify the approach of the car. To make this identification easier, a parameter called the signal-to-noise ratio has been calculated using a simple logarithmic equation that expresses the audio recording as decibels

$$dB = 20\log(V2/V1)$$

Where, log is the natural logarithm function, V2 is the audio recording voltage level and V1 is the noise level in open air. This equation was used with each audio recording and an example of a resulting plot is shown in Fig 2.

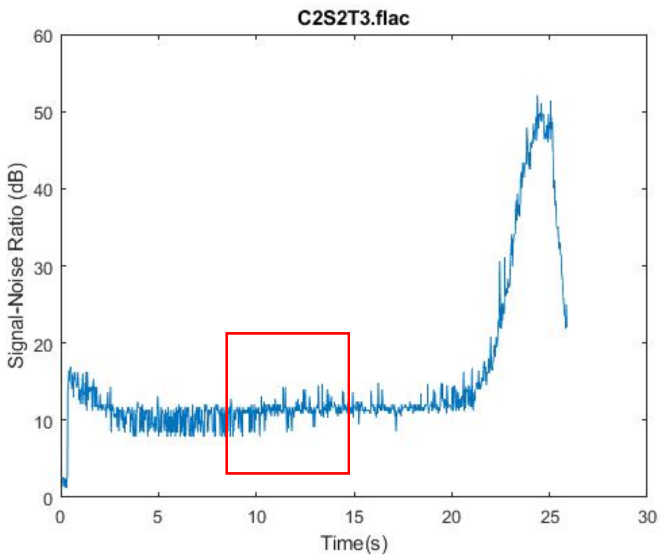

Figure 2 SNR plot of a sample signal

As seen from the Fig 2, highlighted by the red window, there is a noted change in the SNR where the plot changes shape and shifts to a higher average value. The seen values were inaudible in the video recording. This behaviour was seen with several of the trial audio records. This change was taken to be the time point at which the approach of the car was detected by the sensor. In each case, a small, gentle raise in the SNR was seen. The time point at which the raise initiated was recorded in each case and taken note of. This time point was then compared to the earlier noted time points at which reactions from the horses were seen from the video files. It is considerable interest that in most cases, there was a very good correlation between these two values. A comparison of these two results is shown in Table 2. In some of the recordings, there were other environmental noises that interfered with the audio recording making it difficult to distinguish the vehicle noise. The same was the case with some video recordings where the horse was distracted by other noises. In addition, it was also of interest to see if the recorded audio signals had a frequency range out with the audible frequency range of humans (20Hz-20kHz). To understand this, Fast Fourier Transforms (FFTs) were performed on the audio records from the different vehicles. A sample is shown in Fig.3.

Table 2 Time point correlation between audio and video recordings

Car	Horse	Speed	Audio-Time point	Video-Time point
SUV	Cristina	20 mph	16	15
SUV	Cristina	20 mph	17	15
SUV	Cristina	20 mph	10	9

SUV	Cristina	30 mph	14	13
Jaguar	Mafin	20 mph	23	7
Jaguar	Mafin	20 mph	22	15
Jaguar	Mafin	30 mph	10	7
Jaguar	Mafin	30 mph	7,11	2
Leaf	Cristina	10 mph	17,20	14
Leaf	Cristina	10 mph	31	8
Leaf	Cristina	10 mph	23	24
Leaf	Cristina	30 mph	10	7
Leaf	Cristina	30 mph	6	6

As seen, the recorded noise was within the 10Hz-10kHz band, which is within the human audible range. Additionally, to understand the variation of the frequency content of the signal over time, wavelet transforms were performed on a few select signals.

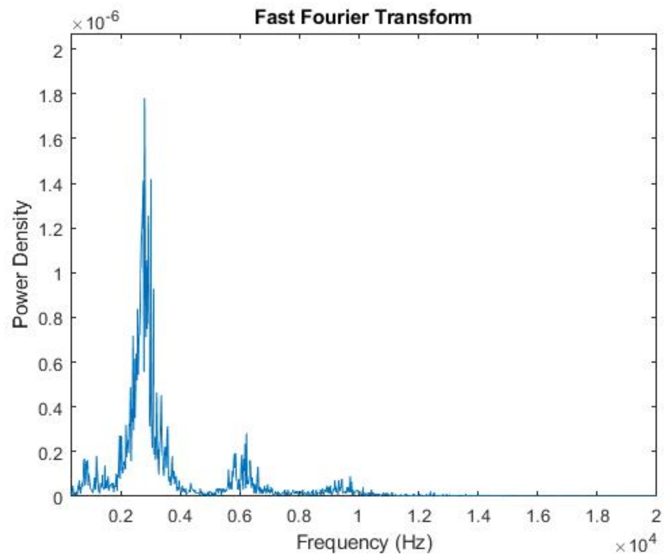

Figure 3 Fast Fourier Transform of a sample signal

As with the FFTs, the wavelet transform did not show any additional frequency content than what was in the audible frequency range as seen from fig 3. With the petrol car, it was quite apparent early on in the video that the horse was aware of the approach of the car. Analysis of the audio signal data showed that the noise levels with the petrol car were much higher than those with the electric cars. The noise was somewhat audible in the video recordings.

5. Conclusions & Recommendations

Based on the above results the general conclusion is that the low-level noises produced by electrical vehicles are being detected by the horses quite early on and they are aware of the presence of the vehicle much before the humans are. Given that this was demonstrated with different horses, vehicles and speeds over several trials, the observation is repeatable and is significant. The strong correlation seen between the microphone data and the video data shows the validity of the data processing methods and of the data itself. This report serves as the scientific evidence to the initial hypothesis that horses are highly sensitive to electric vehicle noise at a distance.

We recommend conducting further experiments in a controlled environment with more vehicles and/or with other conditions in place. As part of the future work, the sensitivity of the horses to electrical vehicles in busier environments needs to be tested. The effect of the presence of multiple vehicles in the vicinity of the horse along with the rider has to be quantified. Various speeds and corresponding noise levels have to be simulated to characterise the response of the horse and consequently the rider. The alertness level of the rider to the horse's reaction and the associated response times has to be understood to increase road safety of both the horse and the rider. Scenarios to consider includes (but not limited to):

i. Horse/EV with no background noise (no other sounds; quiet environment)
   a. Smooth road surface
   b. Low /mid high speed
   c. Variable distance away from the horse/rider
ii. Horse/rider travelling
   a. in the direction of the vehicle
   b. Vehicle coming behind the rider/horse
   c. Electric scooter approaching the horse/rider in Scenario (ii) and (iii)
   d. Electric cyclist approaching the rider in Scenario (ii) and (iii)
   e. Impact of drones/hot air balloons
   f. Multiple horses Scenarios (convoy)
iii. Engagement of
   a. Veterinary and/or horse psychologist in the future studies
   b. Observation of horses' heart beats
   c. vehicle manufacturers (e-scooter; bikes, cars)
iv. Experiments with recorded vehicle noise instead of real vehicle presence (reduce risks of the vehicle/horse incidents)

v. Long term data collection