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Work-related road safety: The impact of the low noise levels produced by electric vehicles according to experienced drivers

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ABSTRACT

The introduction of electric vehicles in urban areas contributes to the reduction of air and noise pollution in these environments. However, the low noise levels produced by these vehicles, previously seen as an advantage, could pose a new risk to the safety of road users. The real magnitude of this issue is, however, controversial. The present study analyses the perception of experienced electric and hybrid vehicle drivers in work situations, something which had not been studied to date. A total of 95 electric car and motorcycle drivers from different public companies in the city of Málaga, Spain, participated in the study. These drivers described risk situations with pedestrians at low speeds, especially in shared streets. They estimated that the risk caused by the low noise levels of these vehicles is "medium". To compensate, many drivers stated that they are more alert while driving an electric vehicle. Additionally, the drivers suggested that equipping these vehicles with continuous external sound was not the most appropriate solution. In the scientific community there is no consensus on the best way to resolve this. Nevertheless, electric vehicles are now required to incorporate additional sound in the European Union and USA. This does not mean that this is a more effective solution. More research on this issue is thus needed, such as studying other non-acoustic solutions or analysing how other road users perceive the risk.

1. Introduction

The World Health Organization has identified air and noise pollution as the most significant environmental causes of ill health (World Health Organization, 2011). The most important source of noise pollution, measured in terms of number of affected people both inside and outside urban areas, is road traffic, which also contributes to higher air pollution (European Environment Agency, 2016). Consequently, the key goals in the European Commission's White Paper on Transport include halving the use of "conventionally-fuelled" cars in urban transport by 2030 and completely phasing them out in cities by 2050, to achieve essentially CO_2-free city logistics in major urban centres by 2030 (European Commission, 2017). Electric vehicles (EVs) play a key role in achieving these objectives. In fact, there are action plans that aim to promote the use of more environmentally friendly modes of transport, avoid increases in traffic flow and raise awareness of noise as an environmental problem (European Environment Agency, 2017). EVs are thus being supported by different strategies in Europe and also internationally. However, the low level of noise produced by EVs, which had previously been considered an advantage, is being questioned and could become a new safety risk for road users.

1.1. Research and regulations

Japan was the first country to consider the possibility that EVs could pose a risk to pedestrians (Ministry of Land, Infrastructure and Transport of Japan, 2006). However, the international controversy began when the United States National Highway Traffic Safety Administration (NHTSA) issued a report concluding that the incidence rate of pedestrian and cyclist crashes involving hybrid electric vehicles (HEV) was greater than for internal combustion engine vehicles (ICE) in certain manoeuvres, such as braking or stopping, backing up, entering or leaving a parking space or turning at very low speeds (Hanna, 2009). Other countries have conducted similar studies. The analysis of traffic crashes in Japan and the Netherlands did not show increased crash rates for HEVs compared to ICE vehicles (JASIC, 2009; Verheijen and Jabben, 2010). Although the UK study (Morgan et al., 2011) showed some results in line with the NHTSA study on incidence rates, it could not determine whether the noise reduction in HEVs was a contributing factor. The NHTSA results (Hanna, 2009) have been criticized because

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the report does not explain the extent to which the absence of hybrid engine noise is responsible for the higher number of pedestrian crashes. Nevertheless, governments worldwide have imposed regulatory speeds, and new regulations in the United States and the European Union propose that all EVs and HEVs must incorporate Audible Vehicle Alerting Systems (AVAS) at low speeds beginning in 2019.

The scientific community recognizes the possibility of problems or risks at speeds below 30 km/h, since at higher speeds tire noise on the road is greater and tends to mask the noise of the motor (Czuka et al., 2014; Garay-Vega et al., 2010; Mendonça et al., 2013; Misdariis and Cera, 2013; Morgan et al., 2011; Stelling-Kończak et al., 2016). At speeds below 30 km/h the HEVs operate in electric mode, so they would present the same problems as EVs. Sandberg (2012) states in practice that the noise difference between EVs and luxury ICE vehicles exists only at speeds below about 20 km/h. Several authors (Cocron and Krems, 2013; Sandberg, 2012) have criticised adding noise to vehicles as a solution and they point to the statistical weaknesses of the NHTSA study. Cocron and Krems (2013) stated that in a simple crash database it is almost impossible to determine whether the low noise emissions of these vehicles, or other factors such as inattention, caused the crash. These vehicles have existed for years on the roads and no one had noticed the problem, which suggests that a technological solution by itself may not solve the problem. Consequently, it is necessary to consider all of the possible solutions, even non-acoustic ones (Sandberg, 2012; Stelling-Kończak et al., 2016), which could improve the detectability of these vehicles while helping to improve noise pollution.

The studies carried out so far are based on the analysis of registered crashes and experiments conducted with pedestrians, especially the blind, in relation to the auditory detectability of vehicles, broken down by type (Czuka et al., 2014; Emerson et al., 2011; Garay-Vega et al., 2010; Stelling-Kończak et al., 2016). Drivers have the most experience regarding the interaction between pedestrians, cyclists and other vehicles, but few studies examine their perceptions. In Germany and Paris, two studies have been carried out, but with drivers that had no more than 6 months experience and less than 15,000 km behind the wheel (Cocron and Krems, 2013; Labeye et al., 2016). No studies have been found on the perception of experienced drivers that include driving during work or that include drivers of electric motorcycles.

1.2. Risk perception

Some authors define perceived risk as “the subjective evaluation by people of the risk they incur in a given situation” (Chaurand and Delhomme, 2013). In the field of road safety, according to Horswill and McKenna (2004), of all the different components of driving skill, only hazard perception or risk perception has been found to relate to crash involvement across a number of studies. Risk perception can be defined as “situation awareness for dangerous situations in the traffic environment” (Horswill and McKenna, 2004) Others such as Machin and Sankey (2008) indicated that risk perception, in relation to driving behaviour, refers to “the subjective experience of risk in potential traffic hazards” (Deery, 1999) and they considered it a precursor of actual driving behaviour. In that way, Groeger and Chapman (1996) claimed that tests of risk perception are worthy of close consideration since they are often considered to be one of the most promising techniques available for improving driver safety.

Different authors have analysed the factors or components that determine the risk perception of drivers (Brown and Groeger, 1988; Deery, 1999; Groeger and Chapman, 1996; Rundmo and Iversen, 2004). In the present study, we have focused on the components of risk perception proposed by Rundmo and Iversen (2004). They stated that to examine risk perception it is necessary to separately evaluate the cognitive or belief-based component and the affective or emotion-based component. They use a *Worry and Concern* scale to measure this affective component. The cognitive component focuses on the way drivers perceive and process information (Brown and Cotton, 2003; Deery and Fildes, 1999; Horvath and Zuckerman, 1992; Machin and Sankey, 2008; Sarkar and Andreas, 2004). Rundmo and Iversen (2004) analysed the cognitive component in the sense of probability of a crash. Similarly, other authors have used this approach (Cocron and Krems, 2013; Ma et al., 2010; Machin and Plint, 2010; Machin and Sankey, 2008; Taylor and Snyder, 2017). In fact, drivers' risk perception has been extensively studied. However, in line with the objective of the present study, as stated above, only two studies were found that analysed the risk perception of EV drivers in relation to the lack of noise (Cocron and Krems, 2013; Labeye et al, 2016). Cocron and Krems (2013) studied EV driverś perceived risk of being involved in critical incidents with other road users due to the low levels of noise produced by their EVs and how this perception changes over time. They concluded that concerns related to the low noise of EVs decrease over time. Similar results were obtained by Labeye et al. (2016), who indicated that silent operation would involve appropriate anticipated driving behaviours, that is, the drivers are aware of the low noise level of EVs and they modify their driving behaviour to prevent risk situations. In order to advance the research, the present study will analyse the perception of experienced drivers in an occupational setting.

The main objective of this paper is to determine the risk perception that experienced EV and HEV drivers at work have of the low noise level of EV and HEV cars and motorcycles in relation to road safety. The specific objectives are focus on determining:

- What is the ***perception of experienced drivers*** with respect to the low noise emission, but more specifically:
  - How drivers perceive the silent feature of EVs in general, that is, if it affects their behavior in driving, makes it difficult to detect or introduces a new risk.
  - Do experienced EV drivers consider low noise of EVs and HEVs as a safety road problem or as an improvement in driving comfort.
  - What is the risk perception of these drivers on the possibility of damaging other road users due to the low noise.
  - What is the level of risk to other users that they perceive due to the low noise.
- What ***risk situations*** they have experienced, that is:
  - How often other road users do not see or hear them and where.
  - What are the characteristics of dangerous situations or crashes that have experienced due to low noise.
- What are the ***countermeasures*** that they believe are necessary.

Based on the questions raised above, two hypotheses are formulated:

- H_1: The level of perceived risk due to low noise emissions of the electric vehicles is different according to whether the drivers were involved in incidents with these vehicles or not.
- H_1^*: The level of perceived risk due to low noise emissions of the electric vehicles is not different according to the type of electric vehicle used by the driver.

No specific hypotheses were made in relation to the types of risk situations experienced or possible countermeasures, as these research questions were exploratory in nature.

2. Materials and methods

This study was carried out during 2016 in the city of Málaga, which is located in Spain's Andalusia region. It is the southernmost large city in Europe and it lies on the Mediterranean Costa del Sol. Málaga covers a total area of over 395 km^2 and it is the sixth most populated city in Spain, the second largest in Andalusia, with a population of 570.006 inhabitants in the 2017 census. In demographic terms it is therefore larger than cities such as Lisbon, Dublin or Manchester.