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On the hazard of quiet vehicles to pedestrians and drivers

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ABSTRACT

The need to produce more efficient and less polluting vehicles has encouraged mass production of alternative energy vehicles, such as hybrid and electric cars. Many of these vehicles are capable of very quiet operation. While reducing noise pollution is desirable, quieter vehicles could negatively affect pedestrian safety because of reduced sound cues compared to louder internal combustion engines. Three studies were performed to investigate people's concern about this issue. In Study 1, a questionnaire completed by 378 people showed substantial positive interest in quiet hybrid and electric cars. However, they also indicated concern about the reduced auditory cues of quiet vehicles. In Study 2, 316 participants rated 14 sounds that could be potentially added to quiet alternative-energy vehicles. The data showed that participants did not want annoying sounds, but preferred adding "engine" and "hum" sounds relative to other types of sounds. In Study 3, 24 persons heard and rated 18 actual sounds within 6 categories that were added to a video of a hybrid vehicle driving by. The sounds most preferred were "engine" followed by "white noise" and "hum". Implications for adding sounds to facilitate pedestrians' detection of moving vehicles and for aiding drivers' awareness of speed are discussed.

1. Introduction

The trend across the world is to reduce the use of hydrocarbon fuels because of predicted future energy shortages and to reduce air pollution in large metropolitan areas. For example, in 1990, the U.S. Environmental Protection Agency's (U.S. EPA) Clean Air Act was amended to encourage automotive manufacturers to build more alternative energy vehicles, such as hybrid (part-gas, part-electric), hydrogen, and fully electric cars. The main purpose of the act was to improve air quality in urban areas such as southern California, where smog has been a major problem. The use of reduced emission vehicles has been shown to be beneficial in reducing the amount of air pollution in certain areas of the U.S. (Meotti, 1995). The State of California has enacted low emission laws that are being met, in part, by alternative energy vehicles. Additionally because of political conflicts in oil producing countries and predictions of future fuel shortages, alternative energy vehicles may also provide societal benefits by reducing fossil fuel use.

Alternative-energy vehicles tend to operate more quietly than vehicles fully powered by internal combustion engines. Hybrid vehicles run partly on an electric motor to conserve gas, but its use also makes them very quiet. Although they are not completely quiet, as there is usually some noise during acceleration and at higher speeds because of tires and wind (Robbins, 1995), they can be much quieter in operation than most current vehicles that are completely powered by hydrocarbon based fuel. Certainly, high-density neighborhoods in urban areas could benefit from reduced noise pollution.

However, the use of quiet vehicles may have drawbacks. One potential problem is the potential effect on pedestrian and cyclist safety. The threat to safety is due to reduced engine noise typical of vehicles on roadways. This issue has been substantiated by news reports of accidents (e.g., Huppert, 2008), a 2006 Resolution of the National Federation of the Blind (Pierce, 2006), and an Act of the U.S. Congress to study the effects of quiet vehicles on pedestrians (Pedestrian Safety Act of 2008).

Sound characterization and localization (Wall et al., 2004) are important in order to gauge where vehicles are coming from and the amount of traffic. Certainly, blind persons would have more trouble detecting and predicting the movement of quiet vehicles. However, non-blind persons, too, may sometimes rely on auditory cues to signal the presence of vehicles. The lack of those cues could result in failing to detect a moving vehicle in their path. Thus, it is vital that some form of noise is heard by both blind and non-blind pedestrians (Wall et al., 2004; Barlow et al., 2005). More pedestrian accidents can be anticipated as directional cues are decreased.

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The reduction of sound emitted by alternative-energy vehicles could affect drivers' awareness of speed. Louder sound from a vehicle's internal combustion engine is usually indicative of faster speed. Research by Evans (1970) indicates that drivers with diminished hearing have a diminished sensation of speed – tending to underestimate it. Anman and Blommer (1999) showed that driving performance is reduced when motor loudness is not matched to vehicle acceleration. Also, Nelson and Nilsson (1990) showed that in complex driving tasks (e.g., shifting gears), performance deteriorates when auditory cues were eliminated. Thus, with the reduction of sound cues in today's quiet vehicles, drivers could be less aware of the speed of their vehicle.

One way to remedy the reduced sound-cue problem is to add sound to quiet vehicles. The added sound to quiet vehicles could benefit both drivers and pedestrians. However, this method is not without some potential issues. One is whether people believe that the issue of quiet vehicles ought to be dealt with. Even if people agree that quiet vehicles present safety concerns, do they believe it should dealt with by incorporating an artificial sound? Still another issue is what kinds of sounds that consumers believe are appropriate for the application.

Simply increasing the sound level is a potential method. Data collected by Björkman and Rylander (1997) indicate that typically noise levels in current internal combustion type motor vehicles positively correlates with speed. Their data suggested that few vehicles (approximately 1%) exceed a loudness level of 75 dBA, which according to earlier research is the lower threshold of annoyance (Rylander et al., 1993). Besides loudness, another critical variable is the form of the added sound itself. One aspect of this is spectral content. If a limited band of frequencies are used, the sound could be masked by other sounds. Also some waveforms might be more annoying than others and thus could be considered less acceptable as an added sound to quiet vehicles. According to Marshall et al. (2007) some in-vehicle alerts (e.g., ones that repeat after small intervals) are perceived as highly urgent and thus are useful as alerts but they are also highly annoying. Therefore, some kinds of sounds could be judged as more appropriate as an added sound to quiet vehicles than others. Studying this issue is important as vehicle sound can give critical information to pedestrians and drivers.

Three studies are described. Study 1 examined people's attitudes toward electric and hybrid cars. Among the issues examined were respondents' interest levels in alternative-energy vehicles, their opinions regarding reduced auditory cues for pedestrians and drivers, and their suggestions for types of auditory cues. In Study 2 another group of participants rated the level of acceptability of 14 sounds if added to otherwise quiet vehicles. Participants were asked to indicate the level of acceptability of 14 types of sounds that were listed on a questionnaire. To increase external validity, Study 3 evaluated 18 actual sounds from 6 categories combined with a video of a hybrid vehicle.

2. Study 1

This study examined people's: (a) interest in alternative-energy vehicles, (b) beliefs about the safety of pedestrians and drivers in relation to quiet vehicles, and (c) suggestions for added sounds.

2.1. Method

2.1.1. Participants

Data comes from 378 individuals living in various locations of the State of North Carolina, USA, but most were collected in Raleigh, NC. Participants were 230 males and 148 females. Ages ranged from 14 to 91 years old with a mean of 26 (SD = 11).

2.1.2. Materials and procedure

The questionnaire contained items that asked participants for their opinions about current technology. Included were items associated with alternative-energy vehicles and issues associated with sound cues. They were:

(1) Electric vehicles are quieter than traditional gasoline engine-powered vehicles. Would this lack of noise pose any threat to pedestrians?
(2) Would you consider purchasing an electric vehicle?
(3) Would you consider purchasing a vehicle powered by a hybrid (part electric/part gasoline) motor?
(4) When crossing the street, have you used the sound of a vehicle as a cue that the vehicle is approaching?
(5) Does the sound emitted from a moving vehicle make you more aware of the vehicle's location and direction?
(6) As a pedestrian, if a moving vehicle were totally silent would that bother you?
(7) As a driver, if a moving vehicle were totally silent would that bother you?
(8) Do you think that including an artificial sound like that of an engine or something else would make hybrid/electric vehicles safer to pedestrians?
(9) What type of sound do you recommend be implemented? (e.g., whistle, hum, engine noise, chimes, etc.).

The first eight items requested yes or no answers. The ninth item was open-ended and asked participants for suggestions/recommendations for the type of sound that could be added to a quiet electric vehicle.

2.2. Results

Table 1 shows the percentage agreement for the yes-no items. Most respondents (72%) expressed interest in purchasing a vehicle powered by electricity. A somewhat larger percentage (83%) responded that they would consider purchasing a hybrid (part electric/part gasoline) vehicle. Most (70%) believed that the lack of noise of an electric car would be a potential danger for pedestrians. A sizeable number (86%) agreed that sounds emitted from a moving vehicle made them more aware of its location and direction. In addition, most participants (73%) said that when crossing a street they have used vehicle sound as a cue that a vehicle is approaching. Approximately half (48%) responded that, as a pedestrian, a totally silent vehicle would bother them. However, only 30% thought that, as a driver, a silent vehicle would bother them. Finally, 68% agreed

Table 1
Percentage agreement for questionnaire items ($N = 378$).

Question item	Percentage (%)
(a) Would you consider purchasing an electric vehicle?	72
(b) Would you consider purchasing a hybrid (motor part electric/gasoline) vehicle?	83
(c) Would lack of noise by electric vehicles pose a threat to pedestrians?	70
(d) Does sound make you more aware of vehicle location and direction?	86
(e) When crossing street, have you used sound as a cue that a vehicle is approaching?	73
(f) As a pedestrian, if a moving vehicle were totally silent, would that bother you?	48
(g) As a driver, if a moving vehicle were totally silent, would that bother you?	30
(h) Do you think that including an artificial sound would make vehicles safer to pedestrians?	68