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The Alarming Sounds of Silence

by

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A few evenings ago, I was driving home from work with my car radio playing softly and my thoughts half-focused on the events of the day. It was a peaceful drive and, since I know the route so well, I felt relaxed and undisturbed by the familiar sights.

Suddenly, the flash of emergency vehicle lights appeared in my rearview mirror. It was an ambulance approaching my car quickly from behind.

Because I was traveling in the left-hand lane of the expressway, I signaled hurriedly to cross over to the right lane. I remember checking behind me for other vehicles before beginning my maneuver. Before I could cross over, the ambulance banked into the right lane and flew around me like a jet in low-altitude flight. Since I no longer needed to change lanes, I took a deep breath and continued motoring home, albeit a little less comfortably.

Once parked safely in my driveway, I realized that I had obstructed an emergency activity, possibly impeding a life-or-death situation. Of course, I did not intend to obstruct the emergency vehicle; I simply was unaware of the vehicle in time to react appropriately. Upon further thought, I recalled that I had seen the vehicle's flashing lights before I heard its siren. In fact, I still can't remember hearing the siren until the ambulance sped by me.

Why didn't I hear the siren in time? My hearing is normal, and I was attentive to my driving. I certainly believe that another driver would have had a similar experience. Perhaps someone should invent an electronic detector that could warn drivers of vehicles that need the right-of-way.

Why it Happened

Although sirens are intended to warn us about the presence of emergency vehicles, it is known that sirens (or train horns for that matter) are not effective indicators to automobile drivers. Their ineffectiveness is understandable when we consider the physical and psychophysical aspects of the situation.

The intensity of emergency vehicle sirens and train horns is about 118 dBA at 10 meters. This sound limit has been established by state and industry regulations to protect us from irreversible damage to our auditory systems and to help us preserve a calm environment. If we stood in front of an emergency vehicle, its siren would sound as loud as a heavy metal rock concert (although I have not attended one of those in more than 20 years).

Several factors dramatically affect the audible qualities of warning sirens and horns. First, the well-known inverse square law of physics tells us that sound intensity is inversely proportional to the distance between its source and its receiver. Figure 1 shows the sound-pressure level (i.e., a physical measure of sounds that correlates with the psychophysical percept of loudness) at a driver's ear for an emergency vehicle siren located at different distances.

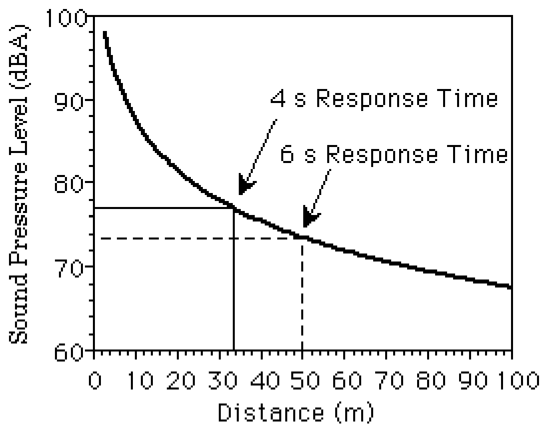

Figure 1. Sound pressure level of an emergency vehicle siren at the driver's ear as a function of distance between the driver and emergency vehicle. Vehicle assumed to attenuate sounds by 20 dBA.

Second, the body of the vehicle attenuates the loudness of external sounds heard inside the car. Although the interiors of luxury cars are quieter than those of other models, sound attenuation of 20 to 30 dBA typically can be measured inside a car with closed windows. The attenuation of sound by the vehicle body is called "insertion loss." The sound-pressure levels shown in Figure 1 include a 20 dBA insertion loss. The curve would be 10 dBA lower if the car body attenuated sounds by 30 dBA rather than 20 dBA.

Third, noise inside a car makes it difficult for drivers to detect sirens and horns. Interior car noise stems from many sources, including the radio or CD player, engine and drive train components, air conditioner/heater fan, the road noise of tires and open windows, and talking passengers. Most importantly, for almost any auditory signal to be detectable, its sound-pressure level must exceed the background noise by about 8 to 12 dBA. This difference in sound-pressure levels is known as the auditory signal-to-noise threshold. Since the interior noise of a car traveling on a modern highway often is measured at about 70 dBA with the stereo off and windows up, one can expect that siren levels of 78 to 82 dBA at the driver's ear are needed to ensure reliable auditory detection.

Figure 1 allows us to compare sound-pressure levels at the driver's ear for different distances between an automobile and an emergency vehicle. For example, suppose that a motorist is traveling at 90 kmh (56 miles/h) and an emergency vehicle is traveling at 120 kmh (75 miles/h). Recalling a few simple physics equations, we can compute that the distance between vehicles decreases at a rate of 8.3 m/s as the emergency vehicle approaches the motorist from behind. If the motorist requires four seconds to respond to the emergency vehicle, such as to change lanes or pull off the road, the driver needs to detect the emergency vehicle when it is 33.3 m away. From Figure 1, we find that the sound-pressure level of the siren is 77 dBA at a distance of 33.3 m.

If the motorist requires more time to respond to the emergency vehicle, the sound level at the driver's ear will be lower. Supposing that six seconds are needed to respond, then the motorist needs to detect the emergency vehicle at 50 m. Referring again to Figure 1, the sound-pressure level of the siren at 50 m is about 74 dBA.

This brief analysis shows that the sound-pressure level produced by a siren does not exceed the auditory signal-to-noise threshold (e.g., 77 versus 78 dBA, respectively), and thus we can understand why emergency vehicle sirens are ineffective. Sirens simply are not loud enough to be heard reliably by automobile drivers. Moreover, increasing the intensity of sirens is not a viable solution, because the resulting sound levels would be too high for people directly exposed to the emergency vehicle.

An Intelligent Solution

Automobile designers seem to be ignoring the driver's need to hear the outside world. Instead of creating innovative ways to improve our sense of the highway surroundings, new automotive designs shield us from hearing the environment. Indeed, some car advertisements boast that their models mute the alarming sounds of road noise, roaring animals, and even nearby thundering waterfalls. Of course, the work to engineer silence inside vehicles does help us hear those new stereo, compact-disk, citizen-band-radio, cellular-phone, fax-machine gadgets! Automobile designers and consumers alike must recognize that these design trends have tipped the scale of safety features versus "creature" features dangerously in the direction of reduced traffic safety.

The rapid development of Intelligent Vehicle Highway System (IVHS) technologies provide some hope that effective emergency vehicle warning systems may be available someday soon. Future IVHS equipment may be capable of helping drivers detect and locate emergency vehicles, trains, and other hazards. These systems might use novel technologies as part of an automated traffic management system; other systems might use existing in-car technologies to convey warning information in more readily perceivable ways.

Figure 2 illustrates a possible IVHS emergency vehicle warning system. This system relies on a radio signal that is broadcast from an emergency vehicle and that is picked up by a directional antenna on an automobile. From the signal, the system determines the presence and direction of the emergency vehicle and then presents the warning information to the driver through in-car audio and visual displays. Because the warning signal is generated "inside" the car, the system could present it at an appropriate level above the volume of other interior sounds.

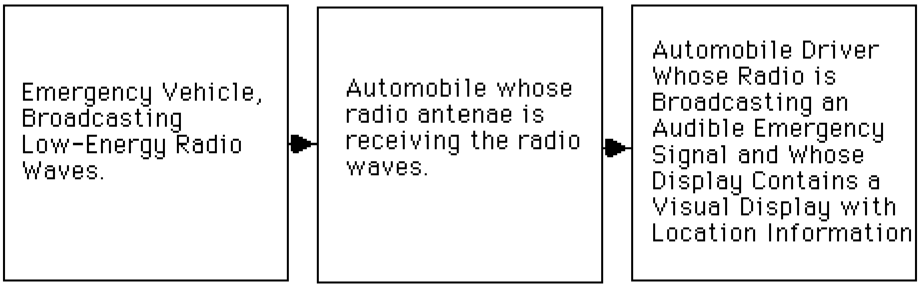

Figure 2. Conceptual components of an intelligent emergency vehicle warning system.

Early detection and localization of emergency vehicles will make highways safer for all drivers. However, the technology announcements in the IVHS arena do not suggest that companies are actively developing intelligent products for this purpose. Rather, many companies appear to be working feverishly to apply IVHS technologies to new problems areas, zipping passed the old problems much like a speeding ambulance trying to avoid a slow-poke motorist. In this haste to commercialize IVHS technologies, we must not forget that many long-standing problems benefit equally from innovative technologies and interventions. It is likely that a balanced engineering approach aimed at solving new and old highway traffic safety problems is needed to make highways and the equipment used on them truly intelligent about safety. Our challenge as human factors engineers is to provide design teams with directions that lead to appropriate and useful advanced technology applications. Imagine -- someday we may even invent an intelligent system to help drivers detect other passenger vehicles and pedestrians.

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