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THE PRINCE OF WALES AWARD

MILLENNIUM PRODUCTS

Siren Sounds

Do they Actually Contribute to Traffic Accidents?

by Dr. Deborah J. Withington.

1 BACKGROUND

In accidents involving an emergency vehicle, a crucial question that is asked is was the vehicle using its siren? A commonly held view is that the use of the siren should aid the vehicle in its progress through traffic, but when the emergency siren is heard, drivers look all around trying to determine from which direction the sounds are coming. The visual cue is required because the sound alone gives no clue as to which direction the vehicle is coming from. The driver is, therefore, not able to make appropriate avoiding action until the emergency vehicle is seen, which is often too late to allow a clear path to be created for the emergency vehicle. This uncertainty regarding the direction of approach costs lives. The incidence of reports in which emergency vehicles have been involved in accidents is on the increase, and those involving pedestrians often have a tragic outcome. Any improvement in the sound quality of the siren, which enables road users to take earlier evading action, will both reduce the journey time and enhance the safety for emergency vehicles attending emergencies and thus strengthen the service provided. It will also be safer for road users, pedestrians and drivers.

The vital physical properties for a sound to be localized with any degree of accuracy are not incorporated into the sound patterns of existing sirens. Indeed, it is recognised that the emergency vehicle siren is "an extremely limited auditory warning device" (De Lorenzo and Eilers, 1991). Auditory localization, i.e. our ability to pinpoint the direction of a sound source, is achieved by extremely complex processing in the brain. The auditory cues used for sound localization depend predominantly on the fact that we have two ears. A sound to the right, for example, will be louder in the right ear than the left, i.e. there are intensity differences between the two ears. Additionally, a sound from the right arrives at the right ear before the left - that is referred to as a timing difference. The external ear flap, the pinna, also makes important differences to the quality of sound. An individual's pinnae are almost as unique as fingerprints and are essential for sound localization. The problem of localization arises from the fact that for any given frequency there is a large range of spatial locations which provide the same auditory cues. Therefore, pure tones, or sounds containing only a few frequencies (which typify existing sirens) are spatially ambiguous and are consequently very poorly localized by our brains. Accurate sound localization is, however, perfectly possible given the right sound in the first instance. We are capable of determining the position of a sound source to an accuracy of 5°. We hear sounds over huge frequency range of about 20 Hz to 20,000 Hz. For a sound to be localizable it must contain as much of this frequency range as possible. Existing sirens operate only over a tiny portion of our hearing range, just 500- 1,800 Hz. It is, therefore, hardly surprising that they cause such difficulty when trying to pinpoint the direction of approach.

In addition to being localizable, ambulance sirens should also be "alerting", in other words, attract the listener's attention. Although it is generally assumed that existing sirens are alerting, this may, in part, be due to familiarity and learned association of emergency vehicles with the existing sounds. The scientific literature on what makes a sound alerting (e.g. Patterson, 1982), indicates that existing siren patterns don't even possess this characteristic in an optimum form.

2 INITIAL LABORATORY-BASED RESEARCH

The localization accuracy of sirens was first tested using a state-of-the-art driving simulator based in the Department of Psychology at the University of Leeds. Approximately 200 participants (age range 19 to 57 years) were tested. They all had previous driving experience. A hearing test, in the form of an audiogram, which tested the ability of each participant to hear a range of frequencies, was performed on most participants. Eight loudspeakers were positioned at

45° intervals around the car's horizontal plane. The speakers were not visible to the participants, and the sound from each speaker was intensity and spectrally matched at a position which marked the driver's head within the car. Matching each speaker in the way described resulted in the only variable each time the sound was played was that of direction. A response panel was mounted by the steering wheel in the car. There were 16 positions marked on the panel which represented the horizontal plane around the car. On hearing a siren sound noise, participant drivers pressed the response button that they judged as equating to the location from which the sound originated. The sound source location was varied randomly, with the constraint that in each session all 8 speaker positions were activated twice. The participants began trials after a period of familiarisation with the car (a 10-minute `drive' along a pre-set rural route). During the trials the participants were asked to maintain a speed of 40 m.p.h. which the experimenter monitored continuously.

Four existing sirens were tested. These were the "hilo" siren characterised by a two-tone sound (670-1100 Hz, 55 cycles/min); the "Pulsar", a pulsating sound (500-1800 Hz, 700 cycles/min); the "wail", a continuous sound rising and falling (500-1800 Hz, 11 cycles/min) and the "yelp", a continuous and fast warbling sound (500-1800 Hz, 55 cycles/min). In each trial the same siren sound was used. The siren sound was delivered at/around road junctions on the test track. In addition to the existing sirens a range of new sound patterns was tested. The new sound patterns contained alerting and a localizable phases which were combined to produce a composite signal.

Data were gathered showing conclusively the poor localization characteristics of existing sirens, though some were better than others; for example, the traditional "hilo" siren is significantly worse for localization than the "yelp". Nevertheless, even the best of current sirens was associated with exceedingly poor front/back accuracy: participants had difficulty identifying whether the sound emanated from the front or rear of the car, to the extent that they were wrong more often than not. It is worth noting that if participants just guessed front or back, in theory they would have been correct 50% of the time. In contrast, with the newly created sound patterns from the University, the corresponding judgements were made correctly most of the time.

The new sounds consist of rapid frequency sweeps, and associated with each train of frequency sweeps is a burst of broadband noise. The aggregate pattern optimises both the alerting and localizing features of a sound configuration.

3 FIELD TRIALS

The next stage in the development of the new sirens was to take the sound patterns which had worked so well in the laboratory and subject them to field trials.

The new siren was tested in field trials with West Yorkshire and London Ambulance Services, the Fire Service in Leicester and the Police in West Yorkshire. The trial locations included very busy city centres through to rural environments. The field trials were essentially similar with each of the services. Each trial vehicle was equipped with both old and new sirens plus a video camera and recorder. A researcher was present during the 3 month trial with each service. Data were collected, in the form of video footage of road-users responses, when either the old or new siren was in use. With the police trials the restriction in terms of space meant that only one siren could be fitted at any one time. Data were first gathered with the old siren (4 weeks) then with the new siren for 8 weeks.

The aim of the analysis was to monitor both the existing auditory warning system and the new auditory warning system in operation on actual emergency journeys using video recording apparatus. This video footage provided an objective record of the interrelationship between the emergency vehicles and the other road users. The collected data could then be arranged into generalised road user responses towards the emergency vehicle. This standardised code of behaviour provides an accurate classification of typical driving behaviour which was used as a template for comparing the effect of both auditory warning systems through traffic.

For each type of behaviour the cumulation of number of occurrences for each behaviour was recorded which allowed numerically driven forms of statistical analysis to be performed. This technique is capable of identifying differences in overall performances between the existing and new auditory warning systems.

The presence of an onboard observer was valuable as the observer had the advantage of understanding the context within which the data were gathered originally. Thus, the coding was more sensitive to the experience of the emergency crews. Translating the video data into a coding system which can be processed numerically allowed a reliable comparison of the effectiveness of auditory warning systems. Thus, the chosen analysis had relevance, reliability and validity.

Video recordings of every emergency journey during the trial period were taken whilst using either the old or the new siren. The video data formed an accurate record of the oncoming road traffic which the fire crews experienced on a day to day basis.

Thus, a comparison of the old and new siren video footage highlighted any difference in the responses to the old versus new siren sounds.

Precise notes on each emergency journey were also taken by the on board researcher. Factors such as weather conditions, appliance position, duration of journey and type of emergency were considered as potential variables relevant to the emergency journey.

The police, ambulance and fire service trials produced very similar results. Most notably road-users reacted quicker, resulting in more appropriate, well signalled manoeuvres. In all trials there was an increase in the number of signalled manoeuvres (e.g. police increased by 20%). Furthermore, as a consequence of the better reactions by other road-users journey times (which could be measured in the ambulance and fire trials) were cut by as much as 10 and 8.5% respectively. The emergency vehicle drivers, in all services, found the new siren disconcerting to drive with at first, due to the reduced noise levels of the new siren compared to the old, inside the cab. However, by the end of the trials the majority of drivers had become accustomed to the lower noise levels. Research has shown that high noise levels in the cab should be avoided for many reasons. It is well documented, for instance, that loud noise levels affects drivers' ability to perform complex tasks (such as driving).

In summary, the data from both the laboratory and field trials indicate that if fire engines are fitted with sirens that produce optimally alerting and localizable sounds, they can be made safer, both for their occupants and for other road users, and they will be able to travel more swiftly to and from emergencies as necessary.

4 REFERENCES

- De Lorenzo, R.A. and Eilers, M.A. (1991) Lights and siren: A review of emergency vehicle warning systems. Annals of Emergency Medicine, 20, 1331-1335.
- Patterson, R. (1982) Guidelines for Auditory warning Systems on Civil Aircraft. Civil Aviation Authority Paper 82017, London.

Author's note:- the Localizer siren is now obtainable from Premier Hazard Plc. The product has 3 different sounds available which correspond to the new siren sounds tested with each of the services, or a version in which the existing "yelp" siren is mixed with broadband noise. All are equally effective, however, personal preference may decide which one is used. The availability of 3 sounds allows services within an area to agree, if they wish, whether to allocate the different sounds to Fire/Ambulance or Police. Or, in police pursuits different sounds can be used by each pursuit vehicle.

About the author - Dr Withington holds a Medical research Council Senior Fellowship for her research on the neurophysiological and psychoacoustic properties of sound. Dr Withington has been based in the Physiology Dept at Leeds University for seven years. In 1994 she, and colleagues, through the University of Leeds set up Sound Alert Ltd. to exploit the commercial potential of the uses of directional sound. Sound Alert Ltd. was awarded the Prince of Wales Award for Innovation in 1997.