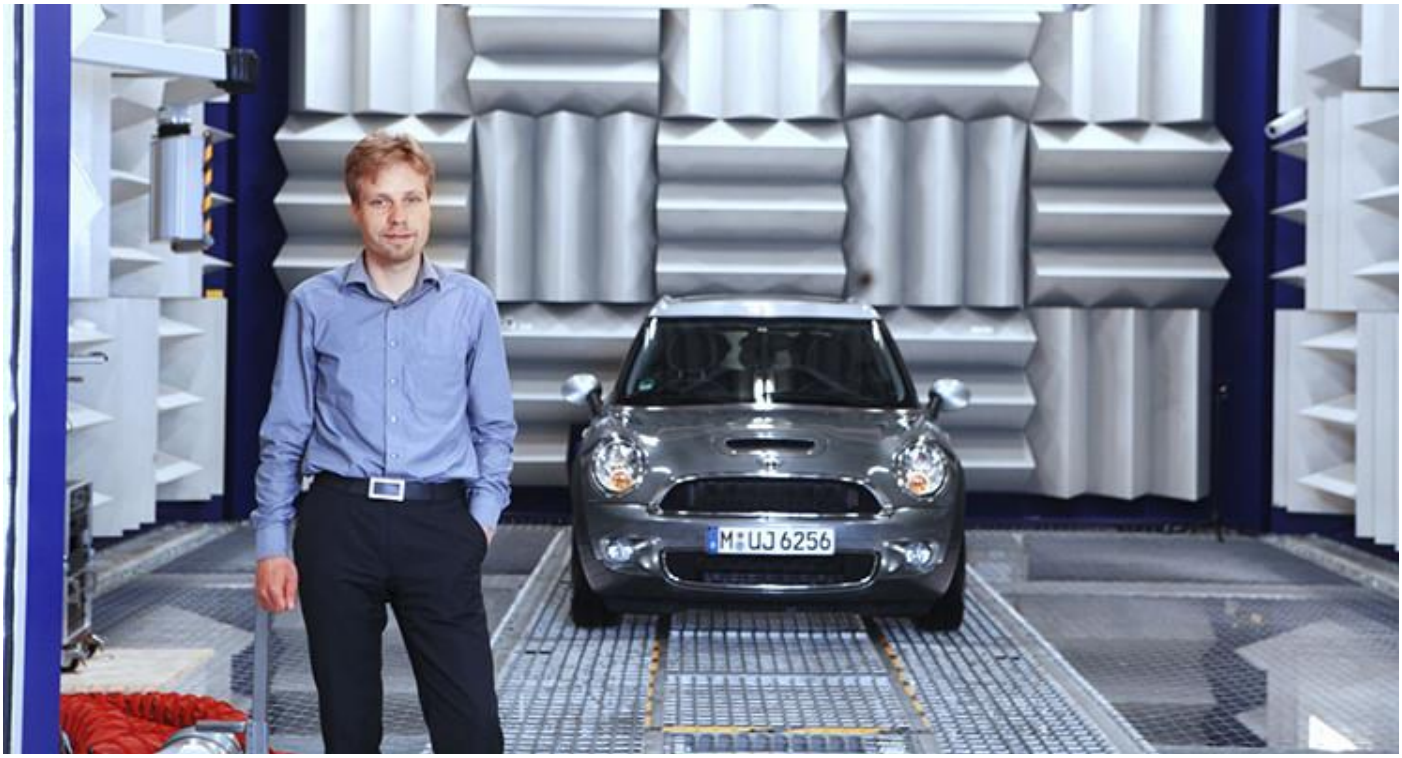
Designing vehicle sounds

Iain McGregor
Online Sound Design MSc Programme Leader, Edinburgh Napier University

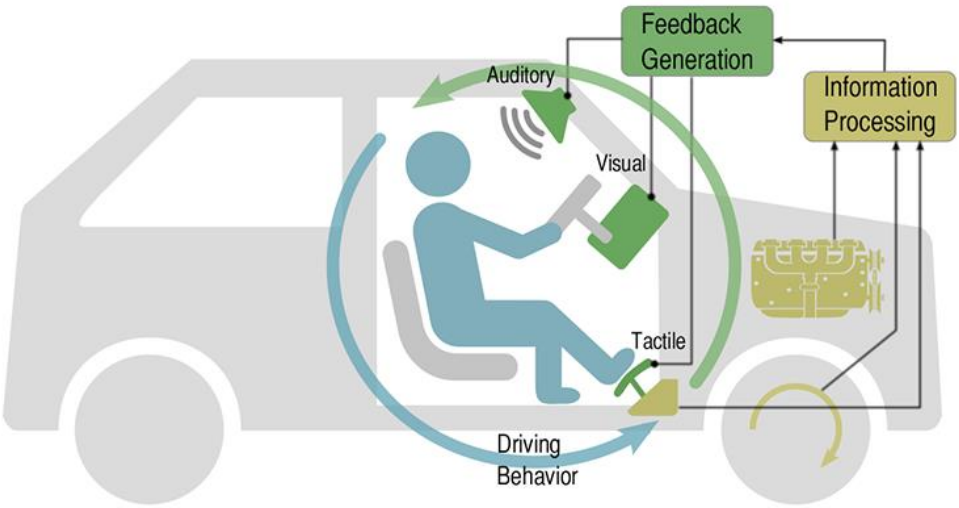


Sound is intrinsically linked to vehicles, drivers use it to monitor their actions and vehicle mechanical condition. Pedestrians and other road users rely on sound to prevent accidents. Motoring authorities in the EU, Japan and USA are concerned about electric vehicles' absence of easily perceived sound and have passed regulations to ensure that vehicles will generate sound artificially. Designing sound for vehicles is not a new concept. Car engines and exhausts have regularly been tuned to produce the right 'note' so that customers feel that the engines are sufficiently powerful. Consequently, some manufacturers place microphones on the exhaust system to replay the sound inside the car to reassure owners that their car is indeed powerful, even generating synthesised sounds. At least one manufacturer performs an audio test on each car that comes of its production line, utilising a short, specialised circuit and a human driver, to ensure that no unusual sounds are present, which might make owners doubt the build quality of their car. Other manufacturers perform acoustic surveys to establish the perceived luxury of switches, doors and locks, amongst other mechanical components, in order to alter the manufacturing process so that in final use each aspect of the vehicle instils sonic confidence.

Sound currently provides drivers with information about the speed that they are travelling at (amongst other things), through the propulsion (engine/exhaust), aerodynamics, or road (tyres). Although not currently implemented future research might include the following. Global Positioning Satellites (GPS) and speedometer readings can easily be combined so that if an electric vehicle is travelling too fast for a particular area the engine could be made to sound like it is working too hard, or even being damaged. Alternatively, the engine sound might increase in pitch and become louder. If the car has a traditional engine a microphone in the engine bay could be relayed into the cabin, or if it is an electric vehicle then an entirely new strained sound could be generated.

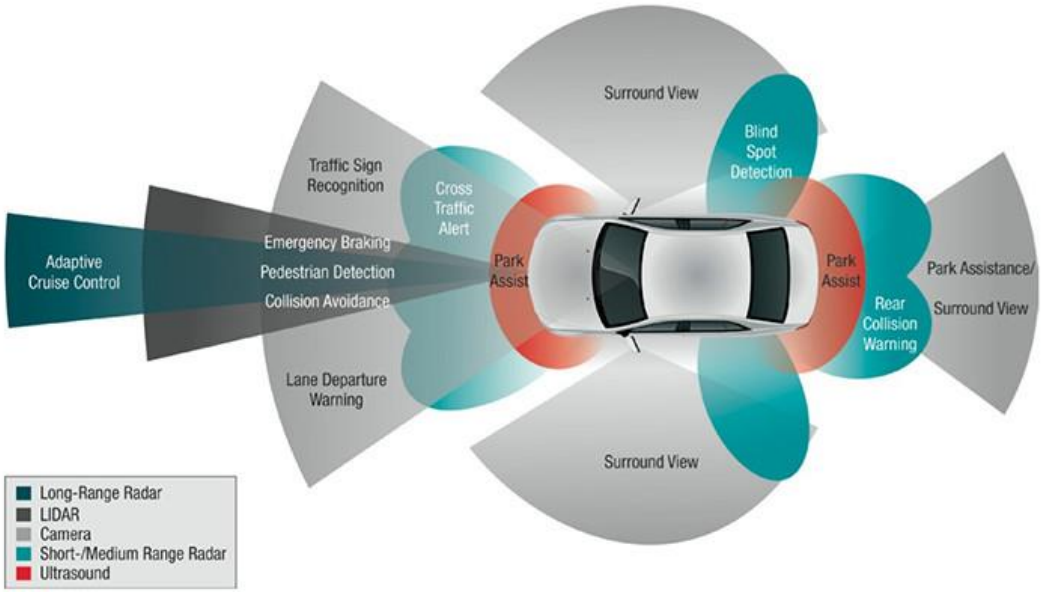


This would also work for vehicles that are too close to the vehicle in front to break safely, and could be further refined through online weather reports or even just monitoring the extent to which the windscreen wipers are being used. The intention would be that the driver thinks that they are pushing the engine too hard and automatically apply less pressure to the accelerator pedal in order to slow down, without the need to learn a new and potentially confusing auditory signal. The system might also be extended to include when traffic lights change in the driver's path, known tailbacks, or even if emergency vehicles are approaching.

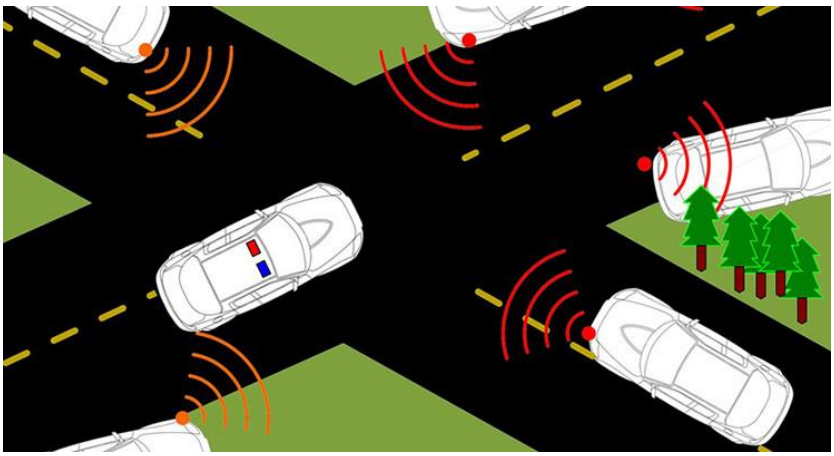


Collision warnings are an essential element of auditory alerts. There are a number of possible of solutions that have already been partially implemented which could be developed further. If a driver has not seen a potential hazard due to a blind spot, often associated with changing lanes on a motorway, then a car horn could be automatically generated inside the driver's car, spatially located from the correct location. This is more likely to produce an immediate reaction than any number of designed alerts, as its meaning will be immediately attributed to another vehicle rather than an artificially generated alert sound. This auditory cue can be altered according to the size of the vehicle detected by a sensor so that trucks produce a different sound to a motor bike, which could make association even easier. If a vehicle is about to change lanes dangerously in front of a car then a screeching brake type sound could be played in the correct

orientation to warn the other driver, or the over-revving sound, so that there is an inherent desire to slow down. If a driver is indicating to change lanes and it is not safe, then an over fast version of their own indicator could be reproduced with a slight Doppler effect to suggest that pulling out at this time would be dangerous due to an approaching vehicle. Audio spatialisation might also help to speed up reaction times, so that the driver would be aware of which direction the potential danger was located.



When a collision is inevitable, and suitable sensors are available, then sound can help either to prepare the passengers for an impact, in a manner similar to an aircraft, or assist the driver to minimise the casualties. Spatial auditory cues can provide information about where the dangers are located. High pitched, loud, asynchronously timed sounds are naturally avoided, and generally disliked. This makes them easily noticeable, so that if it is possible to steer the car in order to minimise the impact of an accident then spatially located cues will encourage the driver to move away from the perceived source. Similarly, if there is a safe zone in a car that passengers can orient their bodies towards, such as away from a door if there was a potential side impact, then this type of system could help reduce the injuries of a collision. All of these systems could also automatically override any audio systems operating in the car such as a radio, talking book or video player so that if audio alerts are not desired then the interior of the vehicle could go silent. This emulates nature, where if danger is sensed it is common for wildlife to remain silent, firstly to be able to hear what is occurring, and secondly to not draw attention to themselves. This removal of sounds is readily understood and is a common trope in media for horror and thrillers, which in turns reinforces the natural instinct in real life through repeated exposure. Making everything suddenly silent can obviously indicate a potential problem, but it also helps prepare a driver and passengers for a dangerous situation, as it can encourage adrenaline production, which in turn improves driver reaction times, hopefully reducing the negative effects of the collision.



Hazard warning systems that mount to car windscreens are already available and can be extended to monitor what is happening inside the car as well. Attention deficits due to task switching or distractions benefit from auditory feedback in order to prevent accidents. Systems that monitor either head movement or eye tracking can easily provide auditory cues about potential dangers that might have been missed, such as if a driver is about to open the door in the path of a cyclist. Many cars already have multiple loudspeakers distributed throughout the vehicle and the sound of a cyclist pedalling at speed with the Doppler effect, and even a bell being emitted from a speaker located in the door about to be opened may be a natural way to warn the driver. This could be extended to if a rear passenger opens a door on the driver's side as well, or if the driver did not glance at their wing mirror before pulling out. Similarly, if a driver has fallen asleep, or become unable to drive, whilst the car is moving, and the vehicle's automation is capable of finding a safe spot to pull over, then an audible alert in the form of an over-revving engine or intermittent horn, in a similar manner to a car alarm could warn other road users to be wary when passing the vehicle, as well as possibly wake the driver.



Audio guidance can also be provided when roads have additional functionally. For dynamic wireless charging roads, cars that are correctly aligned might have a subtle increase in their underlying motor tone to denote that the batteries are successfully charging. This may subtly suggest that the charging is making the vehicle more powerful. A corresponding decrease in pitch could then be used to inform the driver when the road section has finished, or that they are insufficiently aligned and are no longer charging the vehicle. A similar system could be used to indicate the estimated driving range, which can be calculated based up the known destination from the satnav, traffic alerts and driving style. This system does not need to be confined to electric vehicles it could also be implemented in any vehicle, with a complementary warning when a charging point or refuelling location becomes available, with appropriate directions.

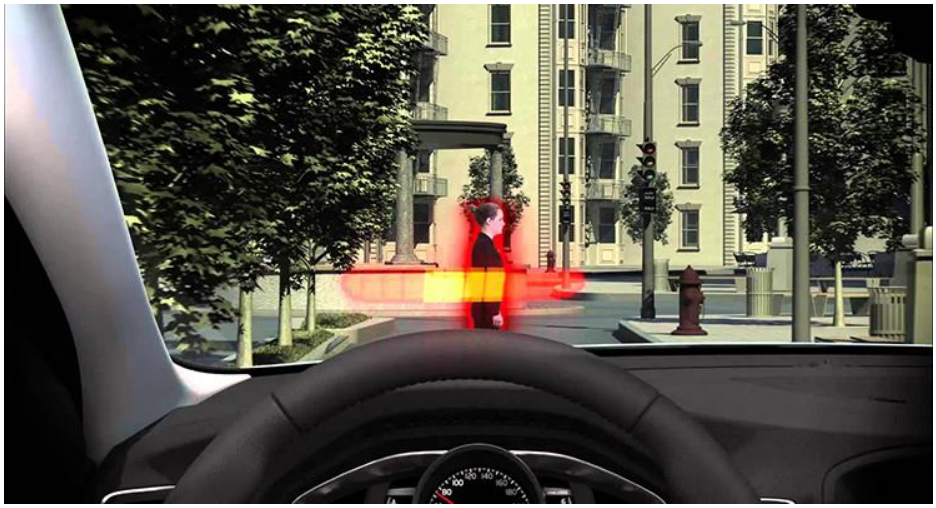


(a) DWC-EV power track under construction (b) DWC-EV in operation

Sound can also be utilised effectively in autonomous (driverless/self-driving) vehicles to give passengers a feeling that they are still in control and make an informed decision to take over driving any time they wish. This might appear counterintuitive as the intention is often for the passengers to forget that they are being driven, and be able to undertake other tasks, such as reading or sleeping. However, in order to be comfortable in a self-driving vehicle passengers have to be familiar with its functions in order to perceive that they are still in control. Audio might be generated to reassure drivers and passengers that the driverless vehicle is functioning correctly and fully aware of all of the surrounding dangers. This is similar to an experienced driver paying more attention to a newly qualified driver, and over time becoming more relaxed as they learn to trust the new driver's skills, eventually even being able to confidently fall asleep whilst they are being driven. At first every sound in a driverless vehicle could be made audible, such as acceleration, braking, indicating as well as even proximity sensors and speed limits. But as passengers become more confident and pay less attention, then all of the sounds could become not as prominent until they are redundant, at which point all artificial cues are removed entirely. However, the sounds could be reintroduced when dangerous driving conditions are encountered for passenger reassurance that the car is aware of, and coping with the difficulties sufficiently.



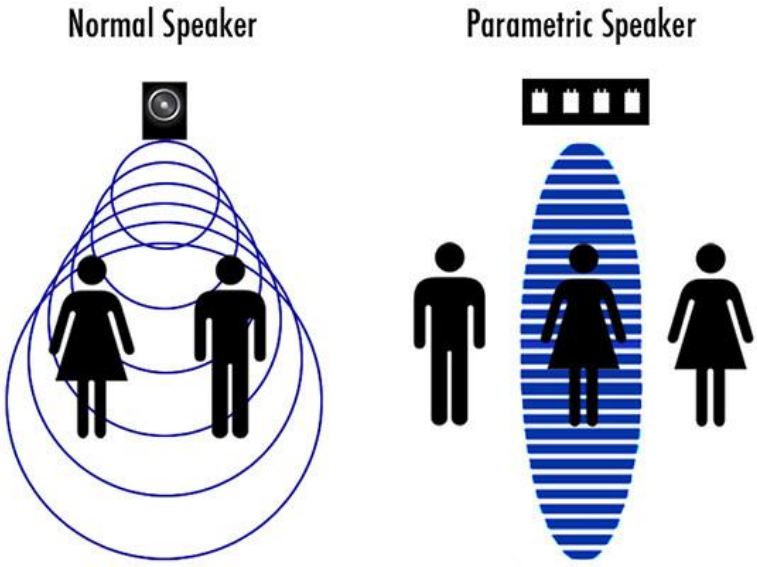
Sensors utilised in an autonomous vehicle are also extremely useful to a manual driver. The technologies designed to navigate safely could be utilised to provide auditory guidance about dangers that the driver might not be aware of. This may be done through spatially locating the potential dangers around the car and exaggerating the sounds that they would make in the real world. Applying the Doppler effect, by making it sound like the vehicle approaching is closer or more dangerous would aid identification. Pedestrians and hazards could also be sonified if the car estimates that it might potentially harm them at its present speed and driving style. Sounds could also be generated externally in order to alert any living creature of the danger approaching them.



Legislation will require electric vehicles to make sound in order to protect other road users, and pedestrians, especially those who are hearing or visually impaired. These currently range from intermittent beeps to continuous tones, and even traditional petrol or diesel engine sounds. Some vehicles allow the generation of different sounds internally versus externally. There will be a wide variety of 'hacks' ranging from replicating classic cars through to comedic sounds, and even the complete absence of transmitted sound as some off switches are already available on vehicles, although legislation in some countries has forced the switches' removal. These sounds could be affected by the speed of the vehicle so that if it is travelling faster, then the sound is louder. It may also be linked to time of day and location, using GPS. That way a busy city centre street during rush hour would have one type of sound, which differed dramatically from a quiet suburban close, late at night. The car itself could measure its own appropriate levels by monitoring the ambient levels and adjust them so that it is always 10 dB above the background until a maximum safe SPL limit is achieved.



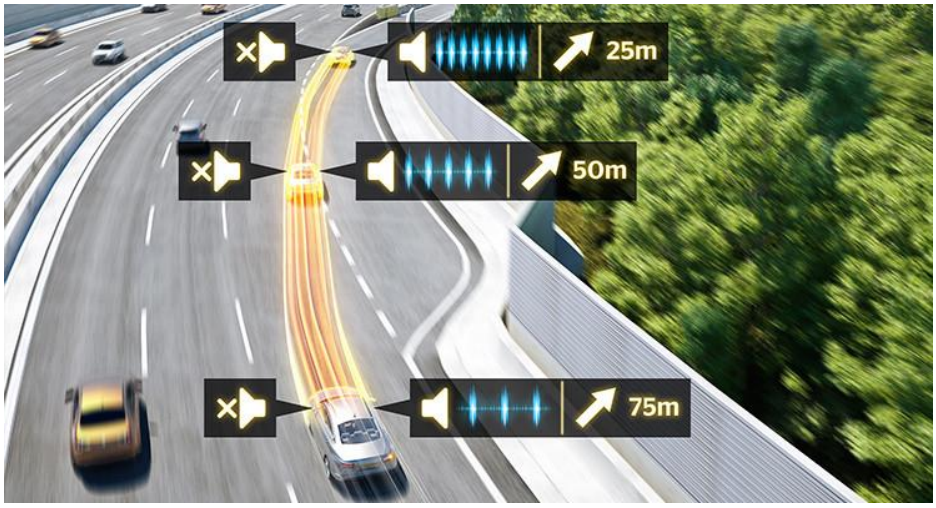
Traditional loudspeakers do not have to be used to generate these sounds. Ultrasound (Holosonic) based systems which have highly directional characteristics could be utilised so that they only operate according to the direction the car is travelling in. Other systems include speakers located in the wheel arches. All of the techniques can be further enhanced so that they only function when pedestrians or other moving vehicles are present in the direction of the car's travel. This could make for much quieter roads, which would also ensure that all of the needed auditory warnings would be more easily heard by anyone within the desired audible range of the moving vehicle. It has been pointed out that some petrol vehicles are now so quiet that the legislation might need to be extend the sound generation requirement to all vehicles.



Speech recognition is becoming increasingly more commonplace in vehicles, but the inherent movement, and its associated sounds can cause problems not encountered in a stationary environment. Luxury vehicles use large amounts of dampening to keep aerodynamic, road and transmission noise to a minimum, all of which are affected by speed. Less expensive vehicles typically have more audible levels of noise, which can obviously affect the reliability of speech recognition systems. This is compounded by all of the additional sounds commonly associated with transport such as radio/music, auditory alerts and conversation. However, having a system always listening out means that it can be integrated into the vehicle so that all auditory alerts are clearly audible, either through omitting unnecessary sounds, or emphasizing key sonic events. The system can also be programmed to listen out for sounds generated by other devices, or even external vehicles, and act accordingly. Ultrasound is particularly useful as an analogue medium of transferring metadata, and this could be used as a form of watermarking to make it easier for vehicles to identify the source and meaning of any sound. The Radio Data System (RDS) for FM radios provides traffic announcements, which can be set to interrupt radio programmes, should the driver wish. In some regions a dedicated traffic message channel is linked to a vehicle's satnav to warn the driver of potential delays, or assist in calculating alternative routes.



Navigation systems are currently almost predominantly speech based, but they can easily be transformed to more intuitive systems that require considerably less cognitive load. The simplest is to simulate the car's own indicator, if this is transposed up an octave, or even two then it becomes much easier to spatially locate for left right orientation. It will naturally overlay the standard indicator when it is operating, and the tempo can be used to represent how far the next turning is. Altering the timing of audible pulses in a manner similar to a Geiger counter has proven successful with parking sensors, and the principle is readily understood. These short beeps can easily be integrated with a voice system so that depending how confident a driver is about the directions they could go between the two systems (speech and audio cue). Custom sounds may also be created so that anything from the sounds of nature (birdsong, wind or river) through to manmade (Racing car, Speedboat or Ice cream van) or even fictional (Pacman, Predator or Tardis). Custom voices have been an option on Sat Navs for a number of years. If two routes are possible and one has delays or might take longer, then both could be presented with the tempo used to indicate the potential impact upon the journey time. Fast moving sounds could suggest that the journey would be quicker in one direction, whereas static or slow sounds could portray potential delays. Existing sounds like a radio playing could also be panned as a gentle reminder, should the driver wish more subtle prompts when they are partially familiar with a journey. Any sound that has high frequency content could be used for this purpose so that it could either be only noticeable by the driver or become a comedy event to amuse passengers as well as provide navigational guidance.



Any auditory cues designed for a vehicle have to first take account of those utilised on mobile devices. Consumers now expect their mobile phones to seamlessly integrate into their new vehicle of choice, and this becomes their primary media interface. Sounds traditionally associated with a vehicle are relatively easy to comprehend due to previous exposure, but novel vehicle sounds that might be similar to those found in a smart phone can understandably cause confusion. This is further complicated by the presence of other media devices, which also can generate a wide range of audio. There is a long tradition of personal customisation within vehicles in order to create a 'bubble' that reflects the owner's personality, and the choice of sound is no exception. A possible solution is to keep as many sounds as possible naturally associated with the vehicle so as to limit the cognitive load and clearly denote which sounds naturally belong with each device, whilst ensuring that they all comfortably co-exist. Drivers and passengers can learn the associations for new sounds, but it is important that these auditory cues never interfere with the main task of driving, whether it is manual or autonomous, especially if a sufficient level of auditory attachment is to be achieved.



Sound is intrinsically linked to vehicles and there are many auditory cues associated with engine, fuel, keys, lights, proximity, seat-belts, tyres, and so on. Typically around 20 designed sounds are present in personal vehicles, but this number is increasing, and is much higher in commercial vehicles. Pleasantness versus annoyance is the usual consideration, irrespective of whether it is an engine start-up sequence designed to greet the owner, or a braking warning. More complex sounds are perceived as belonging to a luxurious vehicle, with simpler ones being associated with a budget mode of transport. Smart phones are starting to be seamlessly integrated into vehicles, which extends the number of interactions possible, from the obvious, telephone, texts and emails to potentially any app that can be imagined. Cars have themselves started to have the moniker 'smart' applied to them, and this extends from 'connected' vehicles all the

way through to ‘fully autonomous’. Familiarity makes drivers feel like they have more control of a vehicle, and by designing sounds can speed up this process. Familiarity can also help reduce cognitive effort, which can potentially make driving safer. Designing sounds that are unfamiliar and difficult to interpret can not only make a car feel unsafe, but also make it unsafe to drive due to the increased cognitive demands. Taking the approach of gradually introducing and eventually removing sounds so that the auditory space evolves according to the driver’s experiences and needs can lead to a more natural intuitive driving experience.



© Iain McGregor All Rights Reserved