# ACOUSTIC SHOCK*

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ABSTRACT: Acoustic shock can be a problem to people, such as call-centre operators, who use headsets to make or receive a large number of telephone calls. A device is described that significantly reduces the likelihood of receiving an acoustic shock.

## 1. BACKGROUND

*The problem:* Occasionally, intense, unwanted signals accidentally occur within the telephone network. These signals are variously called acoustic shocks, audio shocks, acoustic shrieks, or high-pitched tones. The exact source of an individual acoustic shock is usually unknown, but various sources are possible, such as alarm signals, signalling tones, whistles, or feedback oscillation.

The last may be the most common and can easily occur, such as when a cordless telephone is brought too close to its base station while the base station has its hands-free loudspeaker operating. A high-pitched tone then results in just the same way that a public address system squeals when the amplification is increased too much.

Although these high-pitched tones can affect anyone, people using a regular hand-held telephone can quickly move the phone away from their ear, thus limiting their sound exposure to a fraction of a second.

Call-centre operators, however, usually use a head-set, which takes considerably longer to remove from the ear were an intense sound to occur. They thus receive a greater noise exposure than for people using hand-held phones. The problem may be exacerbated if call centres are so noisy that the operators need to have the volume controls on their telephones turned up higher than would be necessary in a quieter place.

*The effects:* Unexpected high-level sounds have been reported to cause a variety of symptoms. Symptoms that have been reported, in diminishing frequency of occurrence, include pain, tinnitus, vertigo/nausea, altered sensations (blocked, hollow, echoing, fullness in ear, burning or tingling), hypersensitivity to loud sounds, headaches, hearing loss, altered psychological state (shock, anxiety, depression, or tiredness), and numbness (Milhinch, 2001). In some cases, symptoms are reported to continue for years after the incident, although more commonly the symptoms are short-lived.

Some operators who experience an acoustic shock understandably feel apprehensive about using the phone or about loud sounds in general. Measurements of loudness perception, based on the Contour test (Cox et al., 1997), performed on 24 telephone operators at a call centre at which several cases of acoustic shock had occurred, indicated significantly abnormal loudness perception. Although loudness perception was normal at low presentation levels, loudness growth was steeper than normal, leading to a loudness of "loud but OK" being achieved at levels 12 dB less than normally occurs.

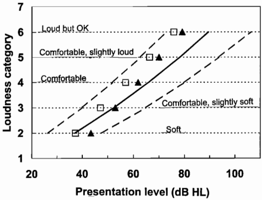


Figure 1. Average loudness growth perception for 24 telephone operators working in a call centre in which acoustic shocks had been experienced. Squares are for 500 Hz, and triangles for 3 kHz. Data for left and right ears have been combined. The solid line shows the mean for normal-hearing listeners, and the dashed lines show the range that takes in 80% of normal-hearing listeners.

*The damage mechanism:* The mechanism causing the adverse symptoms is not known with certainty. It seems highly likely, however, that the sound exposure elicits an acoustic startle reflex (Patuzzi, personal communication). (The same startle reflex can also be elicited by an unexpected touch or puff of air to the eyes). When startle occurs, numerous muscles in the upper limbs, shoulders, neck, eye and ear (the stapedius muscle and the tensor tympani muscle) are activated. If the noise exposure is loud, or if the person is in an aroused state (e.g. anxious, fearful) prior to the startle, the magnitude of the muscular response is heightened. It seems possible that the ongoing symptoms are the after-effects on the muscles and ligaments caused by the muscles being tensed to an unusual degree.

It is well established that the emotional state of a person affects the startle response (Butler et al., 1990; Cook et al., 1991, Grillon et al., 1993). A fearful state, for instance, lowers the threshold of sound at which the startle reflex occurs, and increases the magnitude of the response when it does occur (Cook et al., 1992). It thus seems possible that call-centre operators who fear that they will be injured by an acoustic

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shock may truly be at greater risk of injury than those who are not apprehensive about the likelihood of an incident. If this is true, then incidents are more likely to occur in call centres in which incidents have previously occurred than in call centres in which there have been no previous incidents.

The link between startle response and emotional state opens the possibility that the after-effects of an incident have a self-perpetuating element even without further headset use: Loud sounds normally elicit the stapedius muscle, either with or without a startle response. If such muscle action causes further pain or discomfort soon after an incident, the person affected may become more apprehensive about loud sounds in general, thus increasing the likelihood of further startle reactions. Furthermore, repeated application of the stapedius muscle may even tone and strengthen it, thus enabling it to exert even more force on the structures around it (Patuzzi, personal communication.)

Note that while NAL has extensively researched means to minimize the incidence of acoustic shock (see below), it has not directly investigated the underlying physiological and/or psychological damage mechanisms. The statements regarding damage mechanisms in this report are inferences based on reported symptoms and the known properties of the startle response.

It may be of interest to note that one of the authors once experienced an acoustic shock while wearing headphones connected to some (faulty) laboratory equipment. In this case the symptoms during the exposure (of approximately one-second duration) were a high level of pain and felt similar to being hit about the head. Symptoms in the 30 or so minutes after the exposure included nausea and disorientation. The physical sensations during and after exposure were similar to that caused by an electric shock (which the same author has also experienced).

## 2. SOLUTIONS

The potential solutions to the problem listed below were identified. Digital signal processing code that implemented the first two aspects was devised by NAL/CRC (see Figure 2). This code carried out the operations of automatic volume control, limiting, and shriek rejection. The code included digital filters that were the inverse of response characteristics of particular headphones, so that the code could control the SPL generated by the headphone at the eardrum of the average user. The digital code was installed in a prototype device developed by Telstra that was designed to be inserted between the telephone console and the headset. Over 1000 units of this version, which was specifically designed for Telstra call centres, were constructed by Telstra and installed by them. A general-purpose version, known commercially as the *SoundShield*, has been produced under licence by Polaris Communications for application in any call centre. The device, shown in Figure 3, was designed after considering the following potential contributions to a solution:

*Sound limiting.* Simple headset amplifiers that limit the amount of sound produced by the headsets have not solved the problem. This is understandable; output levels cannot be limited to too low a level, or the clarity and quality of speech is adversely affected, particularly in noisy call centres. Limiting is, however, an important part of the solution so that all sounds, including high-pitched tones, are no louder than they need be. Limiting should be carried out in such a way that it introduces the minimum possible distortion of speech. This requires limiting to be accomplished in several stages, comprising instantaneous, very fast-acting and somewhat slower compression amplifiers. The instantaneous and very fast-acting limiters also minimise the impact of brief "spikes" (clicks, pops and impact sounds). The effectiveness of limiting is enhanced if it is combined with very slow-acting compression to keep the overall level near the comfort level of the operator. Limiting should allow for the frequency response of the headset on the average listener. Such frequency-dependent limiting is necessary if the optimal amount of limiting is to be provided at each frequency.

*Shriek rejection.* As a startle response can occur at levels as low as 60 dB SPL (Blumenthal et al, 1991), it is not possible to prevent startle by limiting alone while still preserving speech clarity. More sophisticated processing differentiates between wanted sounds (such as speech) and unwanted high-frequency sounds, so that each can be processed differently.

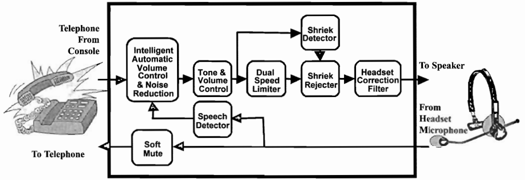


Figure 2: Block diagram of the signal processing devised to minimise the chance of acoustic shock occuring.

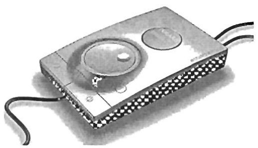

Figure 3: The SoundShield implementation by Polaris Communications of the NAL/CRC signal processing designed to reduce the risk of acoustic shock.

When a high-pitched tone occurs, its frequency can be measured, and of any sound at this frequency blocked. In the implementation devised by NAL/CRC, the tone is typically detected and blocked within a few hundredths of a second. Consequently, the duration and loudness of the acoustic shriek is greatly diminished without speech being much affected.

*Call centre design.* The design of the call centre will greatly affect the level of ambient noise experienced by the operators. Achieving low noise levels enables the average level and limiting level of the headset amplifier to be reduced, which minimises the level at which any unwanted sound occurs. More information about the design of call centres and specifically tailored call-centre services, such as audiological testing, hearing rehabilitation, and acoustic measurements, can be obtained from NAL Consulting.

*Confidence building.* To the extent that the problem has a psychological component, the solution also requires a psychological aspect. If apprehensive operators are more likely to be adversely affected by high-pitched tones, then demonstrating the protective qualities of a headset amplifier to operators may increase their confidence in their equipment and thus decrease the likelihood of incidents. (This assumes that the headset amplifiers are sufficiently sophisticated to provide a high level of protection.)

## 3. OUTCOMES

Tests with a variety of real and synthesised high-intensity, high-frequency sounds revealed that the signal processing was well able to detect and attenuate unwanted narrow-band sounds in the presence of speech. Human acceptance tests on the prototype protection devices were carried out in a call-centre that had previously experienced a high incidence of shrieks. Operators reported that they preferred the sound quality, clarity and comfort of the prototypes, and felt increased confidence that the device protected them from harmful sounds. (The high level of protection provided by the device is easily demonstrated to operators, and developing this confidence by the operators may be an important element in providing a comprehensive solution to the problem.)

The new device, in both the form of the Telstra prototype, and more especially in the commercial SoundShield version, is expected to play a leading part in protecting hearing by reducing the incidence of acoustic shock, especially in call centres. There is considerable interest in take-up of the device, both within and outside Australia.

## ACKNOWLEDGMENT

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