Grant: AFC518-10

Title: Improving Communication in Noise for Miners Wearing Hearing Protection

Organization: University of Connecticut Health Center

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Topic: Advanced Personal Protective Equipment (PPE)

Concept Summary: According to the National Institute of Occupational Safety and Health, one in four miners have a hearing problem and, by retirement age, four out of five mine workers have impaired hearing. Studies have documented that many miners exposed to noise are unwilling to wear hearing protection for fear of failing to understand speech or hear warning sounds. During the last twenty years, specialized hearing protectors (HPDs) have been developed for situations in which noise levels change with time, such as when walking towards or around a machine or when a nearby machine stops operating. In these circumstances, the device automatically adjusts electronically the amount of hearing protection to enable the user to hear more sounds in the environment when the environmental noise is low. These so-called sound level dependent HPDs (sometimes called level dependent HPDs, or sound restoration HPDs) are gaining popularity, and their applicability to mining environments has been studied (Azman & Hudak, 2011). Several have been approved by the Mines Safety and Health Administration for use underground. They employ electronically-controlled sound transmission from the environment surrounding the user to the ear, and for this purpose include a microphone outside the HPD, processing electronics, and a miniature earphone or loudspeaker located inside the HPD. Unfortunately, at the present state of development, the devices fail to improve the intelligibility of speech in the presence of noises commonly leading to overexposure in a mine (i.e., continuous mining machines, roof bolting machines) compared to when conventional hearing protectors are worn (Azman & Hudak, 2011). The method proposed here is designed to improve communication in all situations.

There have been several attempts reported in the literature to improve face-to-face communication in a noisy environment, usually intended for application to hearing aids. Most techniques involve first dividing the frequency spectrum of sounds (i.e., speech or warning sound + environmental noise) into narrow bands of frequencies (so-called "subbands"). The magnitudes of the intensity modulations in each subband are then used to adjust the instantaneous gains applied to the subband signals depending on whether the subband is judged to contain mostly desired sounds or undesired noise. The modified subband signals are then recombined and reproduced by an earphone or loudspeaker for the listener. However, the limitation of these techniques has always been deciding whether the subband contains mostly environmental noise or mostly the desired sounds. In preliminary work for this proposal, we have explored in simulation a method based on signal power for this purpose. The results are very encouraging and suggest that both the intelligibility of speech in noise, and the audibility of warning sounds in noise, can be substantially improved. We therefore propose to confirm the concept in the laboratory by using an active electronic circumaural HPD previously constructed in our laboratory as a "test bed". By using this "test bed" we can avoid time spent on hardware development and construction, and focus on developing the algorithms operating in real time (I.e., so that people can communicate) that will be needed to progress from simulation to evaluation of the concept by listeners. The concept will be fine-tuned at this stage. This will involve using pre-recorded speech and alarm sounds, and laboratory-generated noises that will be processed by the digital signal processor (DSP) within the "test bed" to implement the method developed in simulation. The sounds will subsequently be reconstructed by the DSP for evaluation and, when real-time software is available, presented to subjects in psychoacoustic tests to compare the subjects' performance when using processed versus unprocessed sounds.

At the end of the proof-of-concept phase, confirmation of a successful method for improving communication in noise would, in principle, enable the development of improved personal protection equipment to address the most common complaint of miners wearing HPDs.

With additional funding, a working prototype would be developed, which would involve replacing the "test bed" (which is mounted in a 19" rack and weighs several pounds) by miniaturized electronic circuits contained within a small, lightweight package that could function effectively throughout a work shift and be worn as part of a miner's equipment or attached to, or integrated into, a miner's helmet. The ultra low-powered DSP required for a body-worn or helmet-mounted device will not be code compatible with that of the "test bed" and so the necessary software will also need to be developed. It is anticipated that the prototype would be evaluated by miners or trainees in a simulated mine environment.