

Acoustic Virtual Training for the Blind

by Dean Inman, Ken Loge, and Aaron Cram

1. Orientation & Mobility Training

Individuals who are blind or visually impaired learn to rely on their sense of hearing to compensate for their lack of vision. Learning to “see” using the ears is difficult, and requires considerable time and experience. Fortunately, training programs for the blind, referred to as Orientation and Mobility (OM), have been widely implemented at educational institutions all over the world. In the USA, and many other countries, OM training is provided over the entire course of a student’s public school education. Professionals who provide OM training are known as Orientation and Mobility Training Specialists. OM skill training is defined as “the process of instructing individuals who are visually impaired to maximize the use of their remaining senses to move about freely within their environment” (Blash, Weiner, Welsh, 1997; LaGrow & Weessies, 1994).

The process of learning OM skills is involved, and sometimes dangerous. The unpredictability of motorized vehicles, pedestrians, bicycles, traffic patterns, and changing weather conditions that alter the acoustic qualities of navigable space can make the task of teaching the skills necessary to safely walk along a sidewalk problematic. Clearly, a blind student cannot safely walk alone until basic spatial awareness and navigation skills have been mastered.

Crucial to successful acquisition of OM skills is the individual’s ability to identify and localize acoustical events encountered in their immediate surroundings. To cross a street safely a blind individual must correctly interpret a number of acoustical features of the environment. For example, the student must identify how far away the street is, align their body properly to the crosswalk path, identify the physical traffic lane and intersection configuration they face, discriminate between the directional flow of traffic, the number of lanes to traverse, and the timing of start and stop traffic patterns. A deficiency in any one of these skills can be injurious. So great care, and numerous hours of training are required (Jacobson, 1993).

2. Virtual Acoustic Simulations

The value of simulation has long been recognized in education and training. It is well known that training complex sensory-motor skills can be done effectively and safely in computer simulation environments (Inman, Loge, Leavens, 1995, 1997). Computer generated three-dimensional (3-D) acoustic virtual training environments are an emerging technology that may be used to teach blind children to function in actual acoustic space (Inman, Loge, Cram, 2000). Immersive acoustic training environments make it easy to provide learners with repeated guided and unguided practice, and allow dynamic accentuation of specific auditory stimulus, while selectively diminishing background

“noise,” until the learner develops the necessary skills to know what to “listen for.” The computer can then be programmed to slowly change the perceived “figure to ground” ratio until the simulated situation matches the real world situation after which it is modeled. Other audio parameters, controlled by software, can also be adjusted to suit the specific needs of an individual’s auditory acuity or experience. The versatility and efficacy of a computer simulation to improve human performance, and especially virtual acoustic training, is unparalleled by any other currently existing technology.

3. Sound Localization and Synthetic Sound

In normal hearing humans both ears are used to localize a acoustical information. This is referred to as “binaural” listening. Sound localization refers to the individual’s ability to locate where in the space around them a sound appears to originate. Spatial hearing refers to the “perceived location, size, and environmental context of a sound source” (Blauert, 1983).

Synthetic three-dimensional audio environments have been a proven technology for nearly 20 years. NASA explored the efficacy of spatial audio technology when it created a 3-D virtual acoustic display to facilitate the management and use of inherently spatial tasks involving aircraft cockpits, air traffic control systems, sonar display telemetry, and other multiple-channel human-machine interfaces (Begault & Wenzel, 1990). An off-the-shelf 3-D spatial audio system, using technology adapted from the NASA research, is currently available, and has been used in prior simulation training studies conducted at the Oregon Research Institute Applied Computer Simulation Labs. With this system, a computer sound processing card simulates a real binaural hearing experience by digitally manipulating audio sources in real time through stereo headphones, in a manner consistent with the actual perceptual process naturally performed by the human hearing system (Inman, Loge, Cram, 2000).

With available over-the-counter technology, highly realistic synthetic spatial hearing is now possible. The remarkable technology which allows a 3-D acoustic simulation to be produced by the computer is modeled on the binaural human hearing system, which detects differences in the time required for a sound to arrive at one ear versus the other, as well as harmonic filtering which takes place as a function of the shape of the pinnae, the fleshy outer flaps of the ears. By making use of advanced digital signal processing circuitry, a computer recreates the perceptual effect of real spatial hearing, most effectively through headphones, and is thus able to accurately model actual acoustic spaces dynamically.

As a result of the development of 3-D audio processing hard-

ware in the late 1980s, and the more capable and affordable sound cards that followed, real time 3-D sound applications can now be developed using personal computers (Wenzel, 1991). Since the mid 1990s, the computer gaming industry has begun to embrace the virtues of computer generated 3-D sound. Immersive computer simulation technology is more affordable than it has ever been, and the costs of the computer hardware needed to model a 3-D sound environment after a relevant real-world situation have dropped dramatically, due to the success of the computer gaming industry, which is continuing to exploit immersive sound for game and entertainment titles. For \$20-\$200 dollars (US), depending on performance and fidelity requirements, a sound card capable of creating highly realistic 3-D auditory environments can be installed in most standard personal computers. These cards allow multiple sound source generators, such as automobiles, to move independently of one another, relative to a perceived spherical auditory radius from the listener's head, so the listener is truly surrounded by sounds that model actual acoustic space.

4. Acoustic Virtual Training

The system being used for virtual acoustic training at the Oregon Research Institute Applied Computer Simulation Labs (ORI ACSL) is based on off-the-shelf personal computer technology. The basic system consists of a Windows based computer equipped

virtually being in an actual acoustic space, such as a street intersection location, or a park, while wearing a standard pair of headphones.

After investigating the price and performance of various 3-D sound cards, and their respective hardware drivers, we decided to develop our acoustic training software around the capabilities of the Creative Labs SoundBlaster Live 3-D sound card, which is widely used, well supported, and affordable for public schools and institutions. By fine-tuning some of the 3-D audio Application Programming Interface (API) parameters, we have found the SoundBlaster Live hardware to provide very good spatial accuracy and performance for our OM training purposes, and we expect the fidelity to improve as the technology continues to mature.

The Oregon Research Institute ACSL began developing a series of auditory spatial training environments to facilitate traditional OM training in 1998. Our initial efforts focused on teaching blind students basic sound identification, localization, and tracking skills, but with a four-year grant, funded by the US Department of Education, we have been able to expand our training software to include Internet connectivity and networking. The Internet capabilities of the training system will help OM training specialists work with more students in rural locations, without having to travel to those remote sites as frequently. It will also allow a "central server" to automatically collect performance data



Figure 1: A screen shot from the virtual acoustic training software shows the orientation of the listener's head relative to other sounds presented in the environment. The 3-D environmental sounds can be moved, muted, or isolated with the software. As the student's head turns, the computer adjusts the perceived location of the environmental sounds in real-time.

with a 3-D sound card and a 3-D head-tracking device. The head-tracking unit is a thumb-sized box that easily attaches with Velcro to a small baseball cap worn on the student's head. The head tracker is equipped with tiny gyroscopes that send 3-D positional information to the computer describing the exact 3-D direction in which the blind student is looking. With this information the computer can be programmed to make any number of sound sources appear to emanate and move in any direction around the student's head. This allows the student to hear the sensation of

from each "networked" student, so the results of the acoustic virtual training activities can be assessed. The data collected may include any number of performance parameters, such as the position and orientation of the student's head, which may be compared to the position of a particular sound source in 3-D space. These, and other student performance data, can be measured and recorded accurately in real time. This may help assess the student's ability to accurately localize static and dynamic sound sources, as well as the student's response latency to sound cues.

With the tracking devices currently being used it is possible to accurately measure head movement in 3-D space to within fractions of a millimeter.

The virtual training applications being developed by the ORI ACSL are based upon a widely adopted OM training curriculum developed by the Texas School for the Blind and Visually Impaired called "Teaching Age-Appropriate Purposeful Skills," or TAPS. It focuses on OM activities that students need in order "to move safely and efficiently in home, school, work, and/or community settings as independently as possible" (Pogrund et al., 1995). The TAPS curriculum includes evaluation and assessment methods for functional mobility tasks such as locating specific rooms; auditory discrimination abilities such as tracking a moving sound; directional and positional conceptualization methods to teach, for example, the directional side of a street based on traffic noise patterns; and the development of travel skills in a residential area. Our acoustic virtual training programs are based on skills identified in the TAPS curriculum. We will also use the TAPS protocol to evaluate the effects of Acoustic Virtual Training (AVT) on student performance.

Acoustic virtual training delivered over the Internet will add new perceptual and interactive dimensions to distance education programs for blind and visually impaired students. AVT technology facilitates the creation of responsive environments that react, in real time, to decisions made by the learner. Emerging evidence indicates that students using computer simulation are more active participants in responsive environments in which they become engaged in full body-mind kinesthetic learning (Regian, Shebilske, & Monk, 1992). Such learning combines cognitive, affective, and psychomotor skills as the student pursues his or her own learning strategies (Inman, Loge, Cram, 1995, 1997, 2000; Lanier, 1992; Paton, 1995; Rheingold, 1991; Riva, 1998).

We believe OM training specialists will be able to use AVT environments to teach blind children important functional skills. AVT environments are (a) unlimited, in terms of the different types of training simulations that can be created for the learners, (b) safe, (c) cost-effective, and (d) they make it easy to provide learners with repeated guided and unguided practice. Internet training will allow OM training specialists to reach more children in less time, since they will not have to travel in order to provide at least some of their training activities.

Our current OM research, which utilizes the connectivity possibilities of the Internet, has three primary goals, which are intended to provide teachers of blind students with another arrow in their quiver. These goals include: (1) The development and implementation of training programs that enable blind children to learn important orientation and mobility skills over the Internet; (2) The development of an evaluation system, using multiple measures, that will determine the effectiveness of the training program. (3) Making the program available to teachers and OM training specialists by using the Internet.

We are looking forward to the continued development of acoustic virtual training environments for the blind. We have already seen how computer technology, coupled with a solid foundation of research in human performance and perception, can help lead the blind to faster orientation and mobility skill acquisition. We believe this type of training has the potential to revolutionize how some OM training may take place in the future, and possibly extend the ears of the blind and the sighted, into areas often considered "purely visual." We are investigating, for example, the use of AVT environments to describe difficult physics and mathematics concepts that are often elusive to both the teachers and students of the blind. Regardless of what future developments the AVT environments bring, it is clear that there's

more to education, and virtual training technology, than meets the eye.

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