ECHOLOCATION:

What It Is, and How It Can Be Taught and Learned

by
Daniel Kish, M.A. / M.A.
and
Hannah Bleier, M.A.

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Topics in this document include:

What Is Echolocation?

Echolocation is not a mysterious force or paranormal phenomenon, nor is it a rare gift bestowed by providence upon a chosen few. It is a very natural and easily understood way to perceive the environment. The science behind echolocation is well-known and very basic. It has been studied meticulously by natural scientists for centuries, and psychologists for decades.
Echolocation is simply an aspect of hearing which may be broadly defined as the ability to hear echoes. On the surface, such an ability may seem unremarkable and of little use, because echoes are not commonly believed to be very helpful. Echoes are generally thought to result from specific events like firing a gun in the mountains, or calling out in caves and tunnels. But this is like saying that light reflects only from mirrors and highly polished surfaces.

In actuality, a visual system perceives its surrounds by processing the complex patterns of light as it reflects into the eye from surfaces all around. If all we could see were sources of light and darkness, our eyes would give us very little awareness of the nature of our surroundings. By perceiving and interpreting patterns of reflected light, extremely rich and detailed information can be gathered about the layout and characteristics of surrounding space and objects therein.

Sound can work in much the same way. Vision and hearing are close cousins in that they both can process reflected waves of energy. Vision processes photons (waves of light) as they travel from their source, bounce off surfaces throughout the environment and enter the eyes. Similarly, the auditory system can process phonons (waves of sound) as they travel from their source, bounce off surfaces and enter the ears. Both systems can extract a great deal of information about the environment by interpreting the complex patterns of reflected energy that they receive. In the case of sound, these waves of reflected energy are called "echoes."

Echoes and other sounds can convey spatial information that is comparable in many respects to that conveyed by light. With echoes a blind traveler can perceive very complex, detailed, and specific information from distances far beyond the reach of the longest cane or arm. Echoes make information available about the nature and arrangement of objects and environmental features such as overhangs, walls, doorways and recesses, poles, ascending curbs and steps, planters boxes, pedestrians, fire hydrants, parked or moving vehicles, trees and other foliage, and much more. Echoes can give detailed information about location (where objects are), dimension (how big they are and their general shape), and density (how solid it is). Location is generally broken down into distance from the observer, and direction (left/right, front/back, high/low). Dimension refers to the object's height (tall or short) and breadth (wide or narrow). Just by understanding the interrelationships of these qualities, much can be perceived about the nature of an object or multiple objects. For example, an object that is tall and narrow may be recognized quickly as a pole. An object that is tall and narrow near the bottom while broad near the top would be a tree. Something that is tall and very broad registers as a wall or building. While something that is broad and tall in the middle, while being shorter at either end may be identified as a parked car. Whereas an object that is low and broad may be a planter, retaining wall, or curb. And finally, something that starts out close and very low, but recedes into the distance as it gets higher is a set of steps. Density refers to the solidity of the object (solid/sparse, hard/soft). Awareness of density even adds more richness and complexity to one's available information. For instance, an object that is low and solid may be recognized as a table, while something low and sparse sounds like a bush; but an object that is tall and broad, and very sparse is probably a fence.

Applying Echoes to Movement

The process of navigation and movement can be simply defined as the ability to interact purposefully with the physical environment in a competitive, self-directed way. This simple definition holds for any activity, for any walk of life, even for any species.

The use of echoes instead of reflected light is not uncommon in nature. Some nocturnal birds, many marine mammals, and most bats conduct the majority of their movements without enough light to see by. Many species of bats have extremely limited vision or no vision at all, and marine mammals spend much of their time far beneath the ocean's surface where light cannot penetrate. These creatures have therefore learned to use sound and echo instead of light to provide them with the information they need to survive and flourish. To do this, they send out specialized sounds called echo signals. These signals travel forth, strike every surface in the surrounding environment and return. The process is much like using a flashlight. The sender can interpret the information about surrounding surfaces that the returning sounds carry, much as a sighted creature interpret patterns of returning light. The echoes actually provide real, concrete images of space that we call "auditory" images, that bare many of the same characteristics as visual images. The information contained in auditory images allows non-seeing creatures to hunt the tiniest prey, and to range far and wide without loosing their way.

The best known application of echolocation pertaining to humans concerns submarine navigation. Since the 1940's, submarines have moved through the ocean depths with only a compass and echoes to guide them. Submarines emit pulses of sound that bounce off the ocean floor, reefs, islands, continental formations, or moving bodies, and return to under water microphones. The returning sounds are relayed via stereo headphones to a specially trained technician. It is the technician's job to interpret these sounds, and to guide the submarine and its crew safely through total darkness to the desired destination.

Submarine sonar technicians, practically speaking, are "blind", just like bats and dolphins who live and function in the dark. The use of echoes to enable unseeing creatures to range and feed, and to allow navigation of the ocean's dark depths by man can be readily extended to enhance the movement of blind humans. By the right training and experience, blind humans can learn to fill the darkness with dynamic images derived, not from light, but from sound.

A Brief Guide to Teaching Echolocation

A formal guide to the purposeful instruction of echolocation has been underway for the past several years, and is nearing completion. For now, here are some guidelines and exercise examples to help integrate echolocation skills into your curriculum.

Starting Out

Read this handout through once from beginning to end. Put it down and forget about it for a few days - no longer than a week. Then, pick it up and read it again. Jot down some exercises that you think might be helpful or interesting and try them with your students.

Be creative in developing exercises for your students. While it may be possible to optimize learning through the careful application of formal knowledge and teaching techniques, there is probably nothing that you can do that would be disastrous except failing to insist on enough practice. Some approaches may be better than others, but most have value, and just about any way is better than none. As long as you try enough things over sufficient time, you'll find something what works for each student. If you address and challenge your students' echolocation practice regularly and often, it will flourish in time under just about any condition. Ultimately, the time invested now in enhancing perception will yield more rapid learning, greater skills development, higher performance, and a richer, more rewarding quality of life for your students.

There is no prescribed way to teach echolocation. While the science behind echo phenomena may be well understood and set in stone, the methods of applying that science certainly are not. Think of echolocation as an art, and its development as an art form. Many things are possible, depending on the needs of your students, the environment that you are working in, the items and materials that you have available, and so on.

Though exercises are provided in this guide, you are encouraged to design your own exercises using materials and environments that you have at hand. If you should have need for transparent materials for specific exercises, buy cheap plastic paneling from a hardware store or home-improvement center, or buy scrap from a plastics shop. Otherwise, use cardboard targets, or wood, or even construction or braille paper if it isn't too windy. Use notebooks, clipboards, file folders, stuffed animals, boxes and box lids, whatever is available. And by all means, don't forget the wonders of playground equipment in schools and local parks, objects in parking lots, cluttered sidewalks, deserted churches or other buildings (office buildings, college campuses, etc.), and self-made obstacle courses.

The table of information carried by echoes can be used as a guide to designing and implementing useful exercises in a reasonable progression. Just design exercises that seem to focus on the components in the table. Again be creative, it is hard to go wrong.

Start with basic exercises such as orientation skills with large, simple, nearby objects such as buildings or parked cars. Basic exercises such as the perception of an object location and size usually involves little independent movement, and the space in which they take place can be simple. Movement exercises with smaller, more distant objects are more complex. Perceiving composition (density, texture) is generally the most difficult.

When teaching new echolocation skills, it is recommended that these skills be isolated at first from other skills such as cane use, unless these other skills have been thoroughly mastered. For instance, if you are teaching echo shorelining, turning at corners, or long range echo orientation, it may be best to focus on the echo skills before combining or integrating it with cane use. Good echo skills are no less important than good cane skills, but the combination may be difficult to master for some students. For example, one student who could turn reliably at a T-intersecting hallway without his cane went crashing straight into the wall when asked to use his cane during the exercise. Although both sets of skills should be addressed without excluding the other.

While using the cane, students should always keep alert to echo cues around them, because it is this dynamic awareness which guides and gives purpose to movement - just as vision does. And, while teaching new echo skills, the students should generally carry their canes - even if they aren't actually using them at the moment. One might even guide them initially so that they can concentrate on the echo cues without interference or anxiety, though I would not make a regular practice of this.

It is very difficult for a beginner to attend to all the subtle nuances of echo perception while concentrating on appropriate cane technique and other tactual and kinesthetic cues. Without practice, you are probably unable to tap your foot to one beat while snapping your fingers to a different beat. Most can do each task separately, but it takes practice to combine them. Of course, integration is ultimately necessary where mobility skills are concerned, but the process of fully integrating these skills must be gradual, and learned with much practice and travel experience.

When echolocation skills do begin to integrate with other skills, the skill levels may drop for a time until integration is improved. Be patient, and creative, and maintain encouragement and enthusiasm.

When incorporating exercises, remember three principal aspects of effective travel:

1. Negotiating objects easily without bodily contact

2. Not departing accidentally from pathways

3. Crossing streets or other open spaces quickly and efficiently

Effective echolocation greatly facilitates these skills in ways that no other nonvisual skills can.

A Flexible Hierarchy of Echolocation Development

One can relate the development of echo skills closely to the development of visual skills. Many of the major perceptual issues that affect vision also affect echolocation in a similar way. In brief, a target that is large, close, or stationary is likely to be easier to perceive than one that is small, far away, or moving. Also, a target that is solid is easier to perceive than one that is sparse. A single target is easier to interact with than multiple targets. And, of course, targets in open, simple spaces are easier to deal with than those in congested areas.

STATIC VS. DYNAMIC. Static tasks (tasks requiring little movement) are generally easier than dynamic tasks (tasks where movement is involved). Static tasks simply require less mental processing, and therefore less effort. For instance, it is easier to respond to targets that are stationary than those that are moving relative to the listener. Tracking or following the course of a moving target is generally more difficult than static, directional tasks such as orienting toward or away from a wall. The reason is that tracking a target in motion involves the organization of three primary faculties - knowing where the target is going while it moves (mentally following the target), judging how much and in what fashion one must move in order to maintain a certain relationship to the target, and actually executing the appropriate movements. I draw a distinction between judging the movement, and actually executing the movement. The former is strictly mental, the latter involves translating a mental perceptual structure into physical action - thus becoming perceptual/motor. I believe that the judgment must take place before doing anything, even if the judgment is unconscious or instinctive. In simply orienting to a stationary target, one need only make a judgment of fixed direction and distance. For instance, it is easier to hit a ball that is stationary than when the ball is moving, because the former requires less perceptual/motor processing. Many more judgments must be made to hit a moving ball or shoot a moving target than a target that is stationary.

SIZE. Larger objects are generally easier to perceive than smaller ones. Larger objects usually reflect more sound back to the listener, creating a louder, broader echo. When starting out with skills such as static orientation, try using larger targets first, then smaller ones. When you progress to more complex skills like tracking or avoiding targets in motion, you can resume the use of larger targets again before going back to smaller ones.

DISTANCE. Closer targets are generally easier to perceive than targets far away for similar reasons as listed above.

COMPLEXITY. Generally, the perception of single targets is easier to process than multiple targets or an arrays of targets. Determining the location of one target is easier than determining the relative location of several targets. The exception to this rule involves the comparison of target features such as absorption (soft vs. hard), or dimension. It is much easier to compare two different echo qualities when presented together than at different times. When teaching short vs. tall, for instance, or solid vs. sparse, present both targets at the same time in the beginning. Presenting a student with a target made of wood, and then with a target made of foam, and then asking the student to distinguish which one was foam, is more difficult than if both targets are presented simultaneously. If both targets are presented together, you can ask the student to differentiate between the two targets directly while they are both within the perceptual field. You know that it is easier to match colors when you have the colors in front of you, rather than looking at them separately. If you are trying to determine which shirt goes with what slacks, or what carpet goes with which drapes, you want to see the colors next to each other before deciding. It is similar with echoes.

Every student responds differently to the development of echolocation skills. No hierarchy of skills is set in stone. What is difficult for one student may be easier for another, and visa-versa. For instance, you can go two ways with the training of static or dynamic skills with large and small targets. You can either start with static tasks involving large targets, and then go to dynamic tasks involving large targets before you progress to static tasks involving smaller targets. Or, you can start with static tasks with large targets, and go to static tasks with smaller targets before going to dynamic tasks with large targets. In short, static large to static small to dynamic large vs. static large to dynamic large to static small.

We cannot yet say that either way is better. It seems to depend on the individual student, but you will know which way works best for each student. The key above all, is to maintain a student's interest in the tasks, and motivation to learn. Sometimes we would do 15 or 20 minutes of exercises inside with panels of various sizes and arrangements, then go outside for some natural exposure. Of course, not every aspect of mobility training can be a joy, but if the experience is "spiced" with things that are of interest and relevance to the student, then the student will come to enjoy and appreciate the whole process. "A spoon full of sugar helps the medicine go down." Some students may seem altogether averse to traveling, but it is vital that this aversion be replaced by a desire to explore and discover. For children, this can only be done by associating traveling with rewards or satisfaction. Sighted kids generally obtain this with ease, and many blind kids need to learn that they can have this too. The more they practice and are affirmed and supported by others in the development of positive attitudes and competence, the easier it gets.

Helping the student maintain interest and motivation is worth far more than the most carefully designed hierarchy of tasks. I have found that student performance is related more to their motivation than to my knowledge of perceptual learning. For instance, I've often found myself interspersing dynamic exercises between static exercises, because I found that it keeps students interested - especially young students. In my experience, once the student's interest is lost it doesn't much matter what you do. Anyways, what child wants to sit or stand still for half an hour and "stare" at boring things. Would you? Sometimes with some kids, it's necessary to drop what you planned and just go for a walk, go exploring, or come up with an alternate activity. As long as the activity is constructive and informative, what's the harm? Mobility skills can still be developed under such circumstances, often better than by one's carefully thought out plans. You can make an echo exercise out of just about any activity. Many kids love to play around with a tetherball. I would have them find tetherball poles with the incentive that one of the poles had a tetherball. They loved it. Sometimes we would play "find the tree," and, when they did, they might get to climb it (depending on where we were). I encourage tree climbing, though it can be awkward in a school setting. Other times it was "take me to the things you like to play on." These might be monkey bars, swings, the slide, a merry-go-round, etc. Don't think that all your students can already find these things on their own. Blind kids often develop extremely clever ways of milking help out of others. While it is often surprising what blind kids can do and learn, you may also be surprised by what your students don't know, like "how do you get to the jungle-gym from the slide." Blind kids who just follow the sighted kids all the time may not know. With one kid, I would pick him up and spin him around in a toy airplane to get him totally disoriented. He had a blast. Then we would practice finding the slide from where I set him down. He loved it! Sometimes it seems that being a good O&M specialist means having a good knack for intrigue and entertainment as much as a professional background in nonvisual perception and kinesthesis.

Special Exercise Tips

Try not to be surprised or disillusioned if students have difficulty locating narrow objects like poles, even when they know the object is present. This task is deceptively difficult. Random search patterns are common, especially for young children. In the beginning, always have the student turn to face the object first, then move straight toward it. Sometimes you will have to remind them to keep facing the object while they search.

If a student is traveling in a circle around an object, tell the student not to "loose" the object. The perception of increasing distance can be subtle for beginners and needs to be reinforced. If the student appears to be lost, ask him to turn and face the object, then to return to the object and try again. They can often do this from impressive distances.

Although some may be gifted with superior echo skills, most students can learn to use echoes to enhance their movement. The key is experience. Strong echo skills are learned slowly and with much effort and practice. Therefore, the development of good echolocation depends on continuous, regular practice and reinforcement. Even in lessons not specifically dedicated to echo skills, spend at least five minutes at the beginning of every lesson to practice an assortment of echo and listening skills. During such lessons, draw attention specifically to echo cues in the environment such as when passing distinct objects along a route.

What is Detectable?

These measures vary widely among students. They are based on a combination of psycho-physical research and theoretical knowledge, observation of dozens of students over many years, and over 30 years of personal experience.

A pole of about an inch diameter can be perceived at about two feet. A fire hydrant may be perceived from several feet away, but not up close unless the student is very short. Likewise, a 4 inch curb is also easier to detect from distances of about 3 to 10 feet, but not too close. A chainlink fence may be detectable at 6 to 10 feet. A parked car may be perceived at 10 or 15 feet; add another 5 feet for a van or truck. A tree may be detectable from 15 or 20 feet. A large building is detectable for hundreds of feet with a strong echo signal.

While features in terrains such as mounds, large rocks, up-curbs, or mud puddles may be detectable, drop-offs are almost impossible to detect.

Low objects such as curbs seem taller than they are from several feet away. These may be difficult to perceive up close.

Although echoes are quiet and subtle, echoes from large, hard, nearby objects are extremely pronounced once you know what to listen for. It becomes ridiculous for blind people to run into a wall as it is for sighted people. Excuses for running into easily detectable things should not be made for the blind anymore than the sighted. We admonish sighted children for their clumsiness or inattention: "You should watch where you're going." The same attitude should be held for the blind.

Using Appropriate Echo Signals

What kinds of echo signals are best to use? Are cane taps sufficient? Does it help to click one's tongue, clap, listen for footsteps, or snap one's fingers? Are there echo signals that should be discouraged? What about the social appropriateness of echo signals? The answer to these questions are very simple, and easy to implement. Teaching echolocation is not rocket science. It actually becomes quite intuitive with just a few things to keep in mind.

A sound that produces an echo (called an "echo signal") is like a light, really. You can activate a light, shine it about your environment, and capture feedback by how the light reflects from surfaces in the environment. If the quality of the light is bad - too bright, too dim, too diffuse, wrong color, obscured, glaring, pointing in the wrong direction, etc., then the quality of the visual image goes downhill. People take great pains to optimize the quality of lighting, especially when they're trying to take good pictures with a camera. In such cases, one can really see the difference lighting can make. Most have had the experience of ending up with lousy pictures because the lighting was bad.

Just like a visual image is dependent on the quality of lighting, an echo is dependent on the quality of the auditory signal producing the echo. If the echo signal is poor, the echo is noticeably poorer. An echo signal can be too loud, too soft, too diffuse, hard to understand, obscured, or confused by other sounds.

There are certain simple principles that explain why some echo signals are better than others. To illustrate, let's consider for a moment one of the echolocating marvels of nature - the bat. Bats periodically emit a high-pitched chirp from their mouths. This chirp has been optimized through millions of years of evolution to elicit the best echo imaging for the bat. With this magnificent chirp, bats can fly anywhere they want to, hunt the tiniest of insects, avoid capture, mate, and always find their way back home no matter how many miles they've traveled. Using this chirp, a bat can pick out an insect the size of a pin head from the midst of a tree or bush, and it can even distinguish an insect the size of a pin head from an actual pin head. Research has shown that if the bat is gagged so that it can't emit its chirp, it won't even attempt to fly, not even for a brief distance. It's grounded. It won't even try to use the chirps of other bats to help it fly.

Why won't the bat fly if it can still hear where it's going, even if there are other bats around? The answer has to do, at least in part, with the way sound travels. When something happens to make a sound, say the chirp of a bat, that sound tends to travel in straight lines away from whatever made it - the way the spokes of a wagon wheel extend from the wheel's center. The sound continues to travel until it either fades out, or runs into something. When it runs into something, it simply bounces off whatever it ran into, and comes right back the way it first came - right back to the source of the signal. When the bat makes a chirp, that chirp travels out in all directions, bounces off all the stuff that's around, and comes straight back to the source of the sound, which is the bat's head. That's how bats get such wonderfully clear images of their surroundings, by using the information that comes right back at them from those surroundings. So what happens when one bat can't chirp, but there are other chirping bats around it? Well, all the chirps that are happening around the poor bat are all returning back to their original sources - the other bats. The gagged bat is hearing some reflections from all the other chirping, but the reflections are blurred and unclear - out of focus. It would be like a hiker with no flashlight trying to see a treacherous mountain path at midnight by the light of other, scattered hikers' flashlights. You might see something and what you see might even be recognizable to you, but you wouldn't be able to walk safely along the path. The blurred, distorted echoes are not acceptable to the bats, and no power on earth can make them fly.

The principles of sound and echo apply to humans exactly the same as for bats. As with bats, the most effective echo signals humans can use are the ones that bring the most information back to their ears. All sounds create reflections, and those reflections can be used. But not all sounds create the best reflections, or elicit the clearest echo images.

What about cane taps or the sounds of one's own footsteps? These are not bad, because the sounds come directly back to the sender. But remember what happens when you kick a ball; it generally returns to your feet. Likewise, most of the sound just comes back to your feet or cane, and much of that is absorbed or scattered by the ground on its way back. The listener gets something useable, but not as much as if the sound source was closer to the ears.

Hand claps and finger snaps are fairly common among good blind travelers, because the sound returns to a point nearer the ears, so the images are clearer and more useable. However, one needs an extra hand or two to make these signals.

Another signal very common among good blind travelers, especially children, is the tongue click. This technique comes straight out of nature, with the bat being the best example. The tongue click elicits the clearest reflections, because the sound reflects right back to the user's head. Clicks are also short, so the reflection comes back quickly. Clicks can be varied easily in volume or direction to match the requirements of the environment. Tongue clicking does not require empty hands. Soft clicks are sufficient indoors, while much louder clicks may be necessary while traveling in crowds or through traffic. Also, louder clicks may be needed for detecting objects further away, just as stronger light would be needed to see objects from a great distance.

Different people will produce different tongue clicks. When teaching a beginner to produce a tongue click, an instructor can ask the student to imagine that a blob of peanut butter is stuck on the roof of the mouth, and they are using the center part of the tongue to pull the peanut butter away. The center of the tongue should be pressed to the roof of the mouth to create pressure, then pulled away quickly and forcefully, producing a distinct click. If this method doesn't work for an individual, any method that produces a distinct click that gives the listener the necessary information is legitimate. The tongue click that people use to play "giddy-up horsey" with children, made with one side of the tongue against the cheek or molars, is functional. Also, the tongue click people use when shaking their heads and saying, "tsk, tsk, bad girl or boy," with the tip of the tongue touching the palette right behind the top, front teeth, is also functional. The only kind of tongue click that is not recommended is a click where the tip of the tongue touches the roof of the mouth and then the underside of the tongue flops down to strike the bottom part of the mouth. This click tends to be loud and sloppy, and is difficult to control.

Some have raised concerns that clicking may be considered socially inappropriate. One mobility specialist asserted that she thought it made students look "retarded." If this argument had always been applied, spectacle lenses, critical to the visual functioning of so many people in today's world, might never have been used for fear of looking strange. One could logically apply the same argument to using a cane, or a wheelchair, or any critical adaptive device or technique that stands out as unusual, but also changes the lives of those who use them for the better. I can say from personal experience as a longtime, avid echo user and "clicker" that the occasions on which I have been harassed for tongue clicking have been few and far between. My perspective is that form should follow function, not the other way around. Which is more awkward: a blind person who can't find her way efficiently, gracefully and safely from one point to another, or one who gains the information needed to do so by clicking? To deprive a blind child of information that can be gained by clicking is tantamount to forcing a sighted child to go through life with eyes half-closed.

One tool that can be effective and instructional is a hand-held clicker. A person who is still learning to produce an effective tongue click in all situations may be greatly helped by using such a clicker. They can be purchased in toy stores and some specialty shops - usually in the shapes of small insects or animals. Clickers can be effective for detecting large objects from some distance out of doors. There are just three rules regarding hand-held clickers that need to be observed:

1. The clicker cannot be used indoors. Too many reflections come back from too many things.

2. The clicker can't be pressed too close to the ears. Clickers are often so loud that they hurt the ears of young children if used too close.

3. Clickers shouldn't be sounded more frequently than once every two seconds. A little time is needed to process information between clicks.

Some students develop the tendency to click very often and rapidly. Partly, this can be a form of self stimulation, but it may also result from a craving for the information that clicking provides. It's something like squinting the eyes. However, rapid clicking is usually more harmful than good, especially for beginners. Besides being obtrusive, it generally elicits too much information too quickly to process efficiently. Information from one click tends to blur uselessly into the next. Have students wait between clicks, and process information from each individual click rather than a volley of clicks. Clicks should rarely be sounded more than one per two seconds and never more than once per second. One exception to this involves movement at high speeds such as running, skating, skiing, or biking. Even so, twice per second should set the upper limit, and this takes lots of practice.

Loud signals are unnecessary in quiet environments such as study places. Since echo signals carry well in quiet places, loud signals can be obtrusive to others, and can yield a lot of unnecessary and confusing information. Kids who use echoes are often unaware that they are doing so. Moreover, they can be unconscious of trying to elicit echoes by such behaviors as tongue clicking, hand clapping, finger snapping, foot scraping, cane banging, or yelling. What they are really trying to do should be called to their attention. If their endeavors are obtrusive, they should be redirected to more discrete and more useful behaviors.

Factors That Affect Echolocation

The distance and detail that echoes can carry depend largely upon the following five factors:

1. QUALITY OF ECHO SIGNAL. In general, strong signals carry furthest, and very short, high pitched signals bring the most detail. A strong signal may carry hundreds of yards under good conditions; a weak signal perhaps a few yards. Signals produced deliberately by the listener are usually better than random sounds from the environment. This is because the listener can rely best on a signal that is under their control, and they are accustomed to the style of information these familiar signals yield. Suppose you wore glasses that changed their focus randomly. You'd hate it. You would prefer the constancy of one prescription at a time. The same is true with echo signals. Those signals produced near the ears typically yield clearer echoes, because echoes return most of their energy to the origin of their signal. Thus, echoes from discrete tongue clicks are easier to interpret than those from cane taps or foot steps. Since echoes are relatively quiet, as much echo energy as possible must be directed to the ears. However, moderately low intensities (the volume of a finger snap) are suitable for most situations. Strong intensities may be necessary for perceiving objects far away, or through noisy environments. Signals repeated too fast can be very confusing.

2. SURFACE CHARACTERISTICS. Large, hard, solid surfaces with concavities or interior angles are usually the easiest to detect at greater distances. Also, objects near the head are typically easier than those below the waist. Large objects can camouflage or over shadow small ones that are near them. Small or sparse objects may require stronger echo signals to detect, but very loud signals can hamper perception when many other objects are present. Wet grass and cobblestones can cast false or confusing images when traversed. Strategic echo signaling will dispel false images, but this requires practice. Some people seem less affected by false images than others. Highly reverberate environments such as bare halls or stair-wells will often require quiet signals to prevent unnecessary and highly disruptive echoes.

3. AMBIENT NOISE CHARACTERISTICS. Background or ambient noise may elicit useful echoes, but it generally serves to mask or absorb echoes, because echoes are relatively quiet. The more ambient noise, the more difficult it generally is to perceive echoes. Strong signals such as hand claps or intense tongue clicking will be necessary to penetrate loud noise such as very heavy traffic or loud music. Such noise may cut detection distance down to a couple of yards, and detailed information may not be available. Conversely, very quiet environments generally necessitate the use of soft signals for the "clearest" information.

4. QUALITY OF HEARING. Broadly speaking, better hearing enables the highest potential for using echoes. However, while high frequencies are required for the perception of small objects and detail on surfaces, most useful echo skills rely more heavily on mid frequencies. Even if hearing sensitivity is reduced across large portions of the spectrum, effective echo navigation is often possible.

5. DEGREE OF VIGILANCE. This is perhaps the most important factor. Because there are many cues that must be analyzed and integrated for successful blind navigation, concentration is often divided among many elements. Since echo information is relatively subtle, it requires at least a moderate degree of continued concentration for effective use.

What Helps or Hinders Echolocation?

Too much guided travel will impede the development of echolocation over the long term. Students, even young students, should be encouraged to travel without guidance except under rare circumstances.

Rain does not necessarily interfere with echolocation, but it can be very distracting.

The perception of echoes may be slightly improved in cold weather or after rain. Sound waves tend to travel better in cold air, and wet objects tend to reflect more sound energy.

Strong winds or noise will hamper echolocation. A strong echo signal is necessary for good perception under these conditions.

Anything that covers or shadows the ears such as umbrellas, hoods, and hats can strongly interfere with echolocation. A strong signal will not help under these conditions, but lots of practice may improve performance.

Years ago, an authority suggested that blind children must wear hard sole shoes to enhance the development of echolocation. This may enhance echoes under some circumstances, but the shoes tend to be uncomfortable, and may interfere with the development of tactual sensitivity and proprioception. It is difficult to maintain proper footing and good support without a strong sense of the ground. Blind children need not wear shoes any differently from sighted children.

Age Factors

With blind kids under six or seven, perception of composition and object identification are especially difficult. These skills often require relatively good attention, analytical skills, and contextual knowledge - all of which tend to increase with age and experience.

Concepts of near and far tend to be hard for young kids, but they'll usually respond if asked: "Which one is the easiest to touch?" Centering or going between are also ideas not understood by young kids. Introduce these concepts gradually.

Young children are more inclined to touch everything, and have difficulty maintaining necessary vigilance and concentration. While touching is not a bad thing, remind kids that they're doing "listening" games right now.

Children under six or seven rarely understand that their sense of surrounding comes from hearing. Asking them to listen for silent objects just seems to confuse and may even agitate them. It is best not to refer to echoes as auditory with young kids. If I make reference to a "listening" game, I do so matter-of-factly, and the children rarely challenge me. Eventually, they get the idea. Older kids, however, generally understand and can make use of the knowledge that their perceptions come from auditory echoes.

With regard to echolocation, most of the things that apply to children should also apply to older people. The thing to keep in mind is that high frequency hearing begins to roll off with age. While high frequencies are preferred for the most clear perception of echoes, they are not required for most useful echolocation skills. When impaired hearing is involved, however, learning will usually take longer, and greater attention will be necessary on the part of the student.

Residual Vision

Most functionally or educationally blind people possess a small amount of residual vision - too little for a visual acuity rating. Typically, this vision seems to have little use, and these people generally seem to function mostly as if totally blind. However, a student's perception of light can make it difficult for an instructor to assess echolocation. It is often hard to know for sure whether the student knows of the parked truck or tree from echoes or the blockage of sunlight. While the refinement of visual skills is crucial even for students with poor vision, echo skills should never be neglected. Indeed, echo information will often surpass visual information for those with very poor vision - especially concerning long range perception. Therefore, a blindfold should be used for one quarter to one half of the lessons with anyone possessing visual form or contrast perception. This will help turn the attention of the student to echo cues, and facilitate its application to navigation. Be sure the blindfold does not cover the ears. If you find dramatic decrements in performance under the blindfold, more work in echolocation is necessary.

Students with light perception or visual memories often confuse echo images with visual images. They seem to "see" what they hear. They may say: "I can still see the wall," even under a blindfold. The brain can interpret echo sensation in a visual reference - causing confusion between the sensory channels. With the exception of very young children, you must explain to students the difference between what they see, and what they hear. The strategic use of blindfolds and isolating headphones or earplugs can be helpful here. Some with poor vision will strain their eyes. But when their use of echoes is brought to their attention and refined, they may find it less necessary to strain. This is especially beneficial to those with fragile eye conditions.

Things to Keep in Mind

Though echolocation is an auditory phenomenon, the experience of it may not seem strictly auditory. To some, particularly very young children, it may seem tactual. People with light perception or visual memories often see images when encountering echoes. This is natural.

Children are often unaware of improvements or decrements in their own mobility as a result of proper or ill use of techniques. It is proper to listen to what they say, but confirm their verbal accounts by carefully observing specific behaviors.

Please keep in mind that, just because a student does not seem to be able to do something does not mean that he really can't. Sometimes, you just have to ask in the right way. This is especially true with young kids. For example, asking young students for verbal responses is generally much less effective than requiring a specific action from them. Asking them to tell you where the target is will probably get you nowhere, but they can often go to the target, or reach for it. Younger students may not be able to turn their body and face the target as it moves around in a tracking exercise, but you may notice them tracking it instinctively with their head even so. A child under six may not know what you are talking about when you asked him to show you the nearest of two targets at different distances, but when you ask her which one can be touched the easiest, she may be able to show you immediately and reliably. Often, you must keep talking in order to help some children maintain their attention. Blind kids often have attention spans far greater than sighted peers, but they can be completely distracted by even the slightest noise, or even the thought of a noise. Talking to them can help keep them stay focussed on the "here and now." For example, "What are we looking for? Remember to turn at the corner. Don't forget the corner."

Continued vigilance is perhaps the most important overall skill that a blind person can develop. Degrees of vigilance will directly affect mobility competence, especially where echo skills are concerned.

Don't be discouraged if great strides that seemed to be made in one day or a week, seems to have gotten lost by the next few sessions. Though I believe effective blind mobility can be learned by most, it is extremely difficult, and is therefore readily affected by the mental state of the traveler - especially in children. It takes a good deal of practiced discipline and traveling experience to reduce the negative effects that mental distraction can have on the performance of nonvisual mobility. It is easy for a sighted person to travel while distracted, because visual navigation is relatively simple. Sighted people almost always have easy access to far more information than they need. The processes involved in navigation are highly simplified for them. The blind, on the other hand, encounter much greater complexity. First, they must work very hard to acquire their information, and despite the extra work, the information available is usually lacking in many crucial respects. Second, the blind must make up for insufficient information by applying highly intensive cognitive skills to fill in the gaps. If someone presented you with a faded, blurred, photograph, you'd have to think about it for a while before you could decide what you were seeing. The blind must engage in this extra processing at every step and every nuance of movement. The load upon the mind can be immense. Therefore, the slightest draw upon the mind will affect the blind person's ability to effectively manage this load. Consider the race car driver. He cannot be thinking much about his personal problems while negotiating hair-pin turns at hundreds of miles an hour with a swarm of other drivers all vying for position. Likewise, the blind traveler cannot find proper footing and maintain good balance, negotiate random arrays of all sorts of objects, and maintain his sense of direction and overall spatial awareness at a reasonable gait while otherwise engrossed. Blind mobility requires far more sustained and disciplined attention than sighted people often recognize or even experience themselves. The closest analogy that a sighted person may understand might be learning to drive. At first, the mental effort required is intensive and anxiety provoking. But in time, most people become acclimated to the increased load, and driving gets easier. However, it takes many hours for most people to become comfortable and competent behind the wheel. My point here is that blind people must learn early to focus themselves in their travel, and reckon with the consequences of failing to do so. This can only be done through intensive training and extensive practice. I don't play around with the importance of mobility. So when I say not to worry too much about the specific way in applying echo training, you can take me at my word. There are two main keys here that are very serious, and must, pervade all facets of mobility instruction:

1. Develop mental discipline in blind travelers so that they are more likely to keep a large percentage of their minds focussed on navigation

2. Develop the skill of navigation to such a high degree that a slight decline in performance will not prove hazardous

Both of these keys require extensive practice and experience on the part of the blind traveler, and sustained yet patient attention on the part of the instructor. This is not a light matter.

A Vital Note

I must stress the need for extensive practice in mobility. Most instructors can only see their students for an hour or so a week, and rarely during vacation time. This is understandable, but if most of the student's independent movement is limited to this time, the student's success <u>will</u> fall deplorably short of potential. Certainly, this amount of formal training is far better than nothing and should be honored, but it is woefully inadequate of the goal of helping students to reach their greatest potential. One can not learn blind mobility in an hour or so a week than one could learn the piano, or a foreign language, or math. It is essential that the blind learn to travel and function independently with security, assurance, and grace.

Independent travel outside of mobility lessons, at home and school, cannot be encouraged enough. Homework should be given in mobility like any other subject. In-services should be held for teachers and peers to facilitate proper treatment of blind kids (E.G., not guiding them everywhere or doing everything for them, or allowing them to sit and do nothing). Also, parents should be directly involved in the course of mobility training. Parents should be encouraged on a regular basis to observe what their children are doing during mobility lessons, and learn why they are doing it. The "why" is crucial, because parents may not possess a professional background in issues relating to blindness. They may have neither the experience nor training that you have, so they may labor under gross misconceptions which will undermine everything that you try to teach. Simply speaking, parents may need your input - not only concerning the specifics of behavior and involvement, but also concerning the development of positive, motivating, and enhancing attitudes toward their blind children. Parents commonly know their children better than anyone else, and it's a sure bet that we professionals have a lot to learn about our students from their parents. In general, a good dialogue between family and professionals helps keep everyone on the same page, working toward the same goals.

Regular interaction must take place between parents and instructors of the blind, even at the expense of time with students. I believe that every hour spent with the family can be worth 10 hours spent with a student. The degree and quality of student learning is almost wholly dependent on the attitudes toward and reinforcement of these lessons at home. Though learning can occur even under the most deprived conditions, any debilitating attitudes in the home absolutely must be addressed before optimal learning will happen for blind students. Also, we need to keep ourselves open to what we can learn from parents and families. They have experiences, and perspectives about blindness that we can only guess at. Having parents present during lessons can be very helpful. Showing the parents how to use the cane or listen for echoes, and demonstrating how to teach and reinforce these things with their children can revolutionize the student's learning. Sending reports and videos home regularly on the child's progress can help maintain interest and belief. An O&M instructor that I know sends videotapes of her lessons from time to time to show parents. These things can be very enlightening, and up-lifting where it is needed. Even if parents can only grasp and apply 10% of what you say, that 10% will carry directly into your students' performance. It is enough to make a big difference for many students. A 10% improvement in vigilance, for instance, can be enough to keep some students from getting lost on their way to school; it can mean the difference between being safe at street crossings or not. A 10% increase in motivation can make the difference between becoming a productive member of society or not.

This all may seem idealistic, and it is. Strong, idealistic attitudes are necessary here, because if a blind traveler's skills are not "ideal", then he lives at great risk both physically and psychologically. Again, the key to good travel is experience. Those who have it will do well. Those who don't, simply won't, no matter how much you struggle to teach.

Strategies for Developing Echolocation in Students

1. **Noticing Strong Echo Signals.** When the student is moving around the house or other environments, help her to notice the presence of strong echoes. For example, many children who are blind love to play sound games in highly reverberate environments such as rest rooms,

breeze ways, or stair wells. Encourage the child to sing, repeat words after you, or clap in the bathroom or garage or other large, uncarpeted places without a lot of furniture or other objects that absorb sound. If the child makes noise in places with strong echoes, she can notice that her voice sounds different in these places than in other places. You can also make a noise in the bathroom and then move quickly out into the hallway where there is less echo, and make the same noise there so that the child can compare. Corners in a room also usually emit stronger echoes than other areas of the room.

2. **Observation.** It is important to know what echolocation skills the student is already using. Stand behind the student at a close enough distance to prevent injury, and observe his existing echolocation skills. For example, instead of requiring him to trail along a hallway, allow him to walk down the hallway in his own way. See if he is able to control his movements between the two walls. See if he seems to be able to perceive when a wall or door is in front of him. Observe if the student stops independently or hesitates before contacting objects in the environment. How directed are his movements? If the student is able to do these things, he may be demonstrating some basic echolocation skills. Some children demonstrate good skills at an early age with no instruction, but good instruction always helps improve skills.

3. **Locating a Building.** Being able to locate a building without tactual guidelines is a very functional skill, since tactual guidelines are often not present. A building is a simple object to echolocate because it is large, solid, and free-standing.

   You will ask the student to move toward a building from approximately 10 feet away while clicking (or clapping) at a regular, moderate interval. The student may stop to listen to her clicks or claps and the echo. As the student gets closer to the building, ask her to notice what is happening to the echo. There will be a source click (from the student) and a reflected click (from the building). When the student is farther away, the source click and reflected click will be spaced farther apart. As the student approaches the building, the two clicks will get closer together, until they are indistinguishable from one another, sounding like one click. Also, the click will sound louder as the student approaches the building. Increase the distance from student to building up to 100 feet as the student's speed and accuracy improve.

4. **Locating Parked Cars, Trees, and Poles.** Using echolocation to detect and recognize such objects allows students to find them at will, avoid them, or use them as landmarks. This exercise takes place in a parking lot or other open space. Mobility instructors often avoid teaching in parking lots, but the fact is that there is no way for blind people to avoid them. Any mobile blind person will probably encounter parking lots and other open spaces frequently, and must be able to navigate them. Teach in a parking lot that is outdoors, on a single level, and not heavily trafficked. Many blind children are interested in cars and enjoy echolocating parked cars. For a young child, the exercise can double as a counting exercise; the child can count them as she echolocates them. Cars are large and solid, and therefore relatively simple to echolocate. Trees and poles may take longer to learn.

   Start by positioning the student close to and facing a car that is parked some distance away from other cars. Ask the student to click and to find the car. As the student's skill develops, lead the student around to disorient him somewhat. (Young children who do not disorient easily may be carried, or wheeled around on a chair, or tricycle.) Position the student so that his body is not directly facing the car, but is at an angle to the car. This way, the student will have to make a definite decision about which way to turn his body. Young children may know where the object is, but will not necessarily turn their bodies to move in the correct direction. They may need reminders to turn their bodies so that the object is in front of them. Eventually, turning so that they are facing an object becomes habitual. As the student's skill improves further, increase the distance to the car. A student may learn to detect a small car up to 15 feet away, and a truck or van up to 20 feet away. As skills improve, reduce the size of the objects being located to trees, basketball hoops, and poles. A basketball hoop may be detected as far as 12 feet away, while a tetherball pole may be detected from 8 feet. Large trees may be detected up to 15 or 20 feet away because of their height and size. However, the shorter a tree is, the harder it is to echolocate the trunk because of overhanging branches.

5. **Locating a Corner in a Room.** Locating a corner in a room is functional for three reasons. First, no matter how large a room is, it almost always has corners, so corners are good landmarks. Second, doors are usually located near a corner, so being able to find the corner makes it easier to find the door. Third, echolocating a corner takes much less time, and is much more convenient, than locating it tactually.

   Lead the student around a room to disorient him. Then position the student near a corner (about five feet away) with his body at an angle to it. Ask the student to find the corner by clicking, clapping, or making some other noise. (One very young student wanted to pretend to be a car, and made engine noises to locate the corner.) Increase the distance from the corner as skill improves. Corners may be detectable up to 30 feet away.

6. **Locating the Nearest Wall When Standing Between Two Walls.** This helps the student develop the skill to center herself between two objects while traveling. This will help develop her ability to maintain a straight line of travel using echolocation.

   Position the student so that she is standing between two walls about six feet apart, and so she is closer to one wall than the other. Ask her to click to identify which wall is closest, and then to reach out and touch the closest wall or travel to it. You can also have the student practice centering herself between the two walls. Increase the distance between the walls as her skills develop. Eventually, the student may be able to center herself in large rooms, or between two distant buildings.

7. **Locating an Opening in a Wall (hallway, open doors, or recesses).** Being able to echolocate openings can be more time-effective than trying to do it tactually.

   Walk with the student parallel to a wall about four feet away while the student clicks. Keep walking until you have passed an opening. Tell the student you have passed a hallway or open door and tell them which side it is on. Then ask the student to take you back into the hallway. Let him lead you while clicking. Increase the distance you walk from the wall as the student's skill develops, until you are walking up to about five to ten feet from the wall, depending on the size of the opening. Wider openings are easiest to detect.

Self Exercises for Stimulating the Perception of Echoes

(Although these exercises are meant for professionals to stimulate your own sense of echoes, you can do any of these with your students as beginning exercises.)

1. Procure a large and small wide mouth container. Glass jars are good; seashells are excellent. Speak into the open air, then into each container. Note how the containers sound different from the open air, and from each other. Close your eyes, and have someone hold the containers in front of you as you speak. Try to hear when the container is in front of you, and which one is the smallest or largest. Have someone else speak, and with eyes closed, guess which container is which.

2. Hold the mouths of the containers to your ear. What do you hear from them? Do you recall the "ocean in the seashell" phenomenon? It is only sound reflecting inside the container. Can you hear the difference between small and large containers? Put each container at each ear simultaneously. Can you hear how each one sounds different? With your eyes closed, have someone present the containers randomly to each ear. Can you tell when the container is present or absent? Can you tell which container is which?

3. Position yourself about a foot from a blank wall. Take a deep breath, and, with eyes closed, pivot your body while slowly exhaling in a "shshsh" sound. What happens to the "shshsh" sound as you turn your face away from the wall? How about toward the wall? While pivoting, try to hear when you are facing directly toward the wall.

4. Position yourself about 4 feet from the wall. Take a deep breath, and, with eyes closed, approach the wall while slowly exhaling a "shshsh" sound. Now, step away from the wall while exhaling. See if you can bring yourself to within 6 inches of the wall without touching it. How about 3 inches from the wall?

5. Stand in the middle of a sparsely furnished room with your eyes closed, and turn slowly while exhaling the "shshsh" sound. See if you can locate the a corner. Begin walking, and see if you can find the corner.

6. In your car (or someone else's), find a residential street with several vehicles parked along it. (A parking lot will not do for this exercise.) Open your window, and as you drive, listen carefully to the sound of your car every time you pass a parked vehicle. The sound fluctuates. If you can get someone else to drive, try this with eyes closed, and listen from the passenger window. The effect is more pronounced here. You may even be able to tell by listening whether the street is heavily lined with parked cars or not.

7. In an area familiar to you, try walking with a blindfold and long-cane. Try perceiving things around you by echoes. Do not try to ascertain exact locations of things, just strive for a sense of things flowing about you as you walk. Try clicking your tongue. Do you hear the shifting directions and distances of things as you move among them? A mobility instructor may find that doing this at least once or twice a week will help them in echo training with students, and to comprehend their own cognitive process struggling to integrate nonvisual information for efficient travel. Your students do this all the time.

8. Try accompanying your better students under a blindfold in an area familiar to you. Practice echo navigation with them. Let them help you. They will love it, and you will both learn something.

World Access for the Blind
4661 Grisham Ave
Long Beach, CA 90805

WorldAccessForTheBlind.org
Toll Free: (866) 396-7035
FAX (562) 428-0800

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