ANGEL SOUND™

Interactive listening rehabilitation and functional hearing test program

http://angelsound.emilyfufoundation.org

Better hearing begins here … let's get started

An interactive listening rehabilitation program for adults and teens

EMILY SHANNON FU FOUNDATION

Love is Forever. Help others is life's true meaning

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1.1 Auditory Rehabilitation

Hearing researchers have long recognized that the brain perceives speech differently when presented with sound via an auditory prosthesis (or, "bionic ear"), compared with sound via a healthy, "normal" ear. The bionic ear or cochlear implant (CI) is an electronic device that provides hearing sensation to patients with profound hearing loss. Although the CI can approximately represent speech signals, speech patterns delivered by the CI may be dramatically different from normal acoustic patterns. Based on early experience with normal hearing, the brain develops a central speech pattern template of normal acoustic patterns. Speech patterns delivered by the CI have less spectral details and are spectrally distorted relative to those previously developed central speech pattern templates.

After implantation, CI patients typically experience a period of adjustment, during which the brain accommodates the new sounds and speech patterns provided by the implanted device. Initially, most patients find that speech is distorted and sounds strange through the implant. Some patients quickly adapt to their new electronic hearing and are capable of good speech understanding within days or weeks after their initial "hook-up" to the speech processor. However, some patients do not adapt to electronic hearing as quickly. While they may understand some environmental sounds like the phone ringing or a door closing, speech remains difficult to understand. For these patients, auditory rehabilitation may help the brain accommodate the new speech sounds from the implant, or at least accelerate the learning process.

As the science and technology of the cochlear implant (CI) has developed over the past 50 years, the overall speech recognition of CI patients has steadily improved. With the most advanced implant and speech processor, many patients receive great benefit, and are capable of conversing with friends and family over the telephone. However, considerable variability remains in individual patient outcomes. Some patients receive little benefit from the latest CI technology, even after many years of daily use of the device. This variability in patient outcomes is reflected not only in differences in speech recognition performance, but also in the time course of adaptation to speech via electric hearing. While some patients may easily and quickly adapt to their implant, others may require an extensive learning period. Hearing healthcare professionals acknowledge that cochlear implantation alone may not fully meet the needs of many patients, and that additional auditory therapy may enhance the benefits of the implant device.

Auditory training, an important facet of aural rehabilitation, has been shown to improve speech comprehension and communication among hearing-impaired patients. However, for a variety of reasons, few hearing healthcare professionals routinely include auditory training in the services they provide to CI patients. According to recent statistics, fewer than 10 % of practicing audiologists offer patients a comprehensive program of auditory training, compared with 16 % in 1990 and 31 % in 1980. Time and cost considerations often preclude the use of such therapy. Given the limited number of speech pathologists working with CI patients and the high costs associated with auditory rehabilitation, it has long been urgent to develop an inexpensive and

effective auditory training system for CI patients, especially for those patients who have the greatest difficulty with speech understanding.

Advances in computer technology have contributed greatly to the latest-generation cochlear implant and/or hearing aid technology. These advances also have allowed for the development of important rehabilitation tools, which may ultimately provide the greatest benefit for those hearing impaired who have difficulty with their device. Motivation is an important factor in successful patient outcomes. With the right tools and resources for auditory rehabilitation, cochlear implant and/or hearing aid users may find the necessary motivation and momentum to get the most from their implant and/or hearing aid.

1.2 Computer-Assisted Speech Training (CAST)

While recent findings suggest great promise for auditory training in cochlear implant and/or hearing aid users, many challenges remain in terms of developing effective and efficient training protocols and materials.

- The generalization of improvement to different speech tests and listening environments;
- "Real-world" benefits are, of course, the ultimate goal of auditory training;
- The financial cost occurred with auditory training;
- The effort associated with CI patients' auditory training. How long must users train before realizing tangible returns on their efforts?

It is critical to develop efficient and effective training programs with advanced protocols and comprehensive materials to minimize the time commitment while maximize training outcomes. It is important to develop training programs with advanced protocols and comprehensive materials that will provide rapid improvement over a relatively short time period, and that training with one protocol/material will generalize to the many listening environments that cochlear implant or hearing aid listeners may encounter in the real world.

After almost 20 years' of extensive research at House Ear Institute supported by National Institute of Health, Emily Fu Foundation (http://www.emilyfufoundation.org) have developed computer-assisted speech training (CAST) technology for auditory rehabilitation based on advanced computer technology, signal processing, psychoacoustic, linguistic, and hand-on working experience with hundreds of cochlear implant and/or hearing aid users. As an auditory training tool, CAST provides some appealing advantages over conventional, site-specific approaches for auditory rehabilitation. First, the cost of individualized auditory training is significantly lower than that with traditional auditory rehabilitation provided by hearing clinics and hospitals. Second, CAST is easily accessible by CI patients, who can practice at home at any time, provided they have access to a computer. Third, patients' progress can be easily monitored and shared with their clinical practitioners. Finally, CAST provides auditory training that is specific to the needs of CI users, and more importantly to the needs of individual CI patients. CAST targets acoustic contrasts that are especially problematic for CI users, as opposed to targeting cognitive/developmental learning. Besides being affordable, accessible, and appropriate for CI patients, CAST has many other unique features.

Feature #1: Comprehensive Training Materials

CAST provides a comprehensive set of training materials with which to train recognition of many kinds of sounds, not just speech. Training materials include simple pure tones, environmental sounds, monosyllabic words, consonant training stimuli (in v/C, v/C/v, and C/v contexts), familiar words, familiar sentences, simple melodic sequences and familiar melodies. For targeted phonetic contrast training, CAST uses more than 1000 novel monosyllabic words (for initial, medial and final vowel and consonant training) and nonsense words (for initial, medial and final consonant training), spoken by four different talkers. Additional training materials and/or training modules can be easily incorporated for individual patients to maximize training outcomes. For advanced users, CAST also can mimic difficult listening environments by adding background noise or competing speech in real time.

Feature #2: Individualized Training Protocols

CAST also provides individualized training protocols for CI patients. The level of difficulty is automatically adjusted according to individual patient performance by increasing the number of response choices and/or reducing the acoustic differences between response choices. During training, both auditory and visual feedback is provided, allowing users to compare incorrect responses to correct responses repeatedly. As performance improves, the level of difficulty is automatically increased. If performance does not improve, the level of difficulty is decreased. At the end of each testing and training session, the program offers training guidance. For example, based on testing or training results, the program suggests the appropriate training level, whether users should go to an easier or more difficult training level, etc. Feedback and encouragement are offered throughout, as the positive effects of good will can help patients build momentum during the rehabilitation process.

### Feature #3: Integrated Training Structures

CAST provides easy integration for auditory rehabilitation between CI patients and their audiologists or speech pathologists. All training and test results are saved in a standardized database. Users can view results and ongoing progress and data can be exported and shared with the patient's hearing health practitioner. Results are automatically saved and include user's name, test and training results, test and training date, training time for each exercise, and total training time. Audiologists can use these results to track a patient's progress over time, check for potential problems with the CI device, and optimize the speech processor. For example, during a clinical visit, the audiologist can review the test results and adjust processor parameters (e.g., frequency allocation, channel gains, etc.) to improve performance in problem areas (e.g., reception of fricatives, etc.). Over a longer term, different magnetic acoustic pressures (MAPs with different parameter settings) can be loaded onto the processor and performance can be tracked over time to determine the optimal MAP; the combination of take-home experience and laboratory testing (with easy access to results) will allow for better long-term optimization of the processor. CAST provides a visually clean and user-friendly graphic interface, allowing patients to concentrate on listening rather than navigating an unfamiliar computer program.

1.3 Angel Sound™:

CAST technology has been successfully transformed into several commercial products (e.g., "Sound and WAY Beyond" from Cochlear Americas). Similar to CAST technology, Angel Sound is an interactive auditory training and hearing assessment program that lets you take control of your listening rehabilitation independently or self-administer your functional hearing test at home. You gain practice in discriminating and identifying sounds and speech components through a series of self-paced modules that cover different aspects of the listening process. The level of difficulty is automatically adjusted to match your developing listening skills. The program provides audio-visual feedback, highlighting areas you can continue to practice. The training and testing results can be shared with your clinician or therapist, who can provide further advice on your rehabilitation. Focused on practice and improvement of your listening skills, **Angel Sound™** compliments your clinic rehabilitation and functional hearing test program.

Angel Sound™ is the latest commercial products based on the CAST technology. Angel Sound is an UPGRADED and FREE version of "Sound and WAY Beyond", an auditory rehabilitation program based on CAST technology and distributed by Cochlear Americas. Angel Sound includes more advanced training protocols (i.e., bilateral training procedures, advanced psychophysical training protocols, animated audio and visual feedback, remote data access, and advanced training customization with favorite setting) than Sound and WAY Beyond. Also, Angel Sound has more advanced training modules (i.e., comprehensive music training, auditory resolution training, and functional hearing test module). The functional hearing test module provides a perfect tool to self-assess your functional hearing with a variety of speech and music recognition tests, including auditory resolution, phoneme, music, speech in quiet and noise, and auditory cognition (short-term memory) etc. Angel Sound provides many advanced features to ensure the effectiveness and efficiency of the program, which are shown as follows.

- Interactive, self-directed modules for adults and teens at all skill levels;
- Comprehensive training materials, including over 10,000 sounds, words, and sentences;
- Phonemic-based minimal acoustic and perceptual contrast training protocols **R**einforce the brain's ability to distinguish between phonemes which are the building blocks of language;
- Psychoacoustic-based adaptive speech in noise training protocols to **E**nhance the listening and communication skills and strategies for the listening conditions encountered in the daily life;
- Comprehensive sound materials and advanced signal processing to **S**imulate the "real-world" listening environment (environmental sounds, speech sounds, speech in noise, and music etc);
- Seamless integration of training and testing to **T**rack the functional hearing status over time as well as the improvement over the course of auditory training.

- Extensive scientific verification for the training protocols and materials used in the Angel Sound program.

| Comprehensive Sound Materials | Advanced Training Protocols | Extensive Scientific Verification |
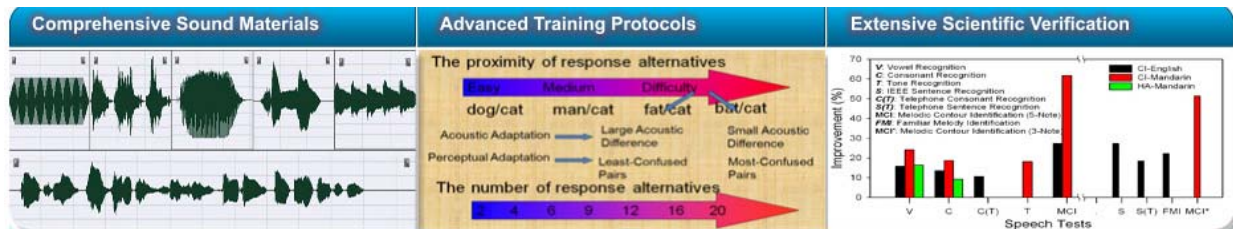
1.4 Download Angel Sound™

Angel Sound is freely distributed by Emily Fu Foundation (http://www.emilyfufoundation.org). There are two options to obtain the Angel Sound software.

Option 1: Online Downloading (for PC only)

Online downloading is the quickest way to access the program. Here is the website link for the downloading: http://angelsound.emilyfufoundation.org/angelsound_download.html

Please click the downloading button shown in the website and download the whole package (with basic module and seven advanced modules). Note that the security software in your computer MAY block the downloading process stating the site (or file) was infected with malware (since the downloading file is executable file). If the downloading does not proceed, please try the following approaches if you feel comfortable about the following: 1) Change security and privacy settings in web browser; 2) Disable security software and firewall temporarily.

After clicking the downloading button in the website, PC will download an executable ("AngelSoundSetup.exe") file into your PC (generally in My Documents\Downloads folder if Google Chrome is used) and the file is located in the left bottom corner. For Window IE users, a window will pop out (Panel 1, below). Click "Run" in the first pop-out window. The downloading will start (Panel 2, below). The downloading may take 30 minutes or longer since the file is pretty large (~476M). After downloading, some PC computers may give a warning message if the computer has virus or other security protection software. Please ignore the warning and continue the installation process. Click the "Run" button (Panel 3, below) to start the installation.
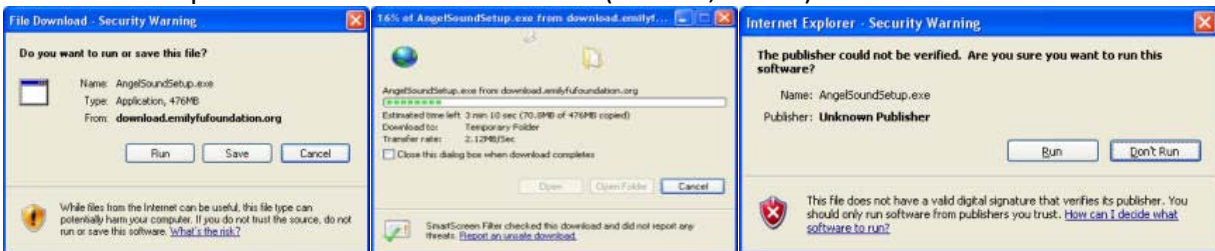
Option 2: Email Request of Installation CD (for PC only)

For users who cannot download the installation file due to slow internet connection or other reasons, the installation CD of **Angel Sound™** will be available free of charge upon request via Email (angelvoice@emilyfufoundation.org).

CHAPTER 2 HOW TO USE

2.1 Installation and Activation

Computer Requirements:

- PC with Microsoft® Windows® Vista, XP, 2000, 7, 8, & 10.
- Macintosh using Parallels Desktop or Bootcamp with Window OS.
- Pentium® III or higher (recommended)
- 500MB free hard disk space, 1GB RAM, 16-bit sound card
- Display/screen resolution of 1024 x 768 or higher

Installation Steps:

Step 1: Insert the **Angel Sound Training** installation CD. The setup program should launch automatically. If not, please go to the **Angel Sound** installation CD and select: "**Setup.exe**"

Step 2: A welcome page for **Angel Sound** installation will display. Click "**Next"** to continue.

Step 3: On the license agreement page, read the license and if you agree with the terms, select "**I accept the terms of the license agreement**" option to continue the installation.
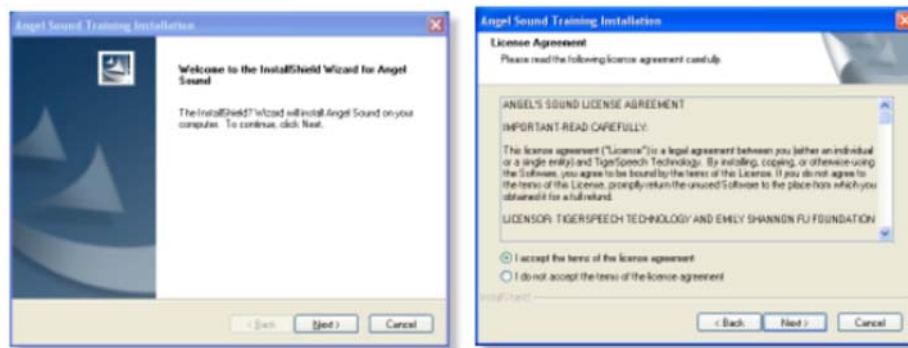

Step 4: When prompted, enter your name and company name. If no company, just enter "Private User".

Step 5: Follow the installation wizard instructions. In general, select the "**Complete**" option. The program will be installed into the default directory, Otherwise, please select the "**Custom**" option.
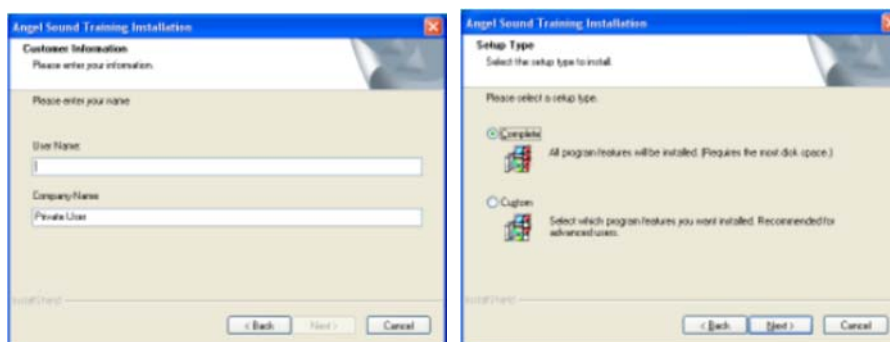
Step 6:   **Angel Sound** is now ready to install the software. Select "Install" button to continue. It may take several minutes to install the software. After installation is complete, click "Finish".
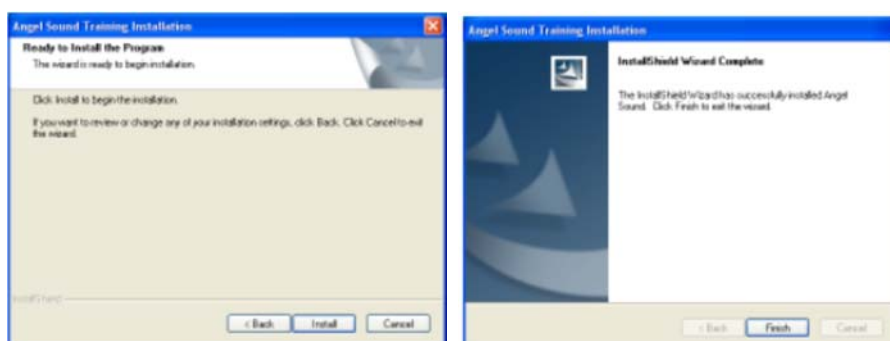

Activation Steps:

After installation is complete, click on the "Angel Sound" icon, which will appear on the desktop [or click Start > All Programs > TigerSpeech Technology > Angel Sound]. The program will launch. Click the "**Please Click to Enter Angel Sound**" button on the bottom of the page.

If your computer is connected to the Internet, the software will be automatically activated. After the program is activated, a "Session" dialog box will open. Enter the session name and click the "Save" button to continue. If your computer does not have internet connection, a manual activation is required to activate the software. A new window will pop out once the software detects the lack of internet connection. Please send the ComputerID, which is shown in the window, using the following email address (angelvoice@emilyfufoundation.org) to obtain the activation code.
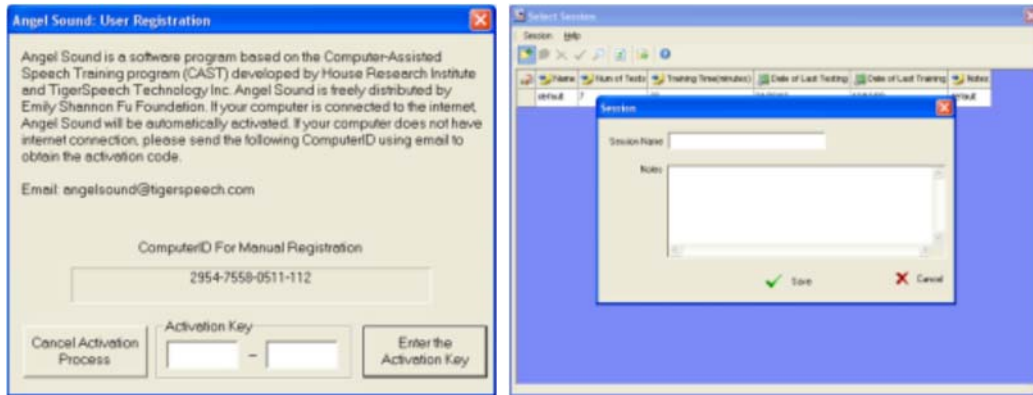
2.2 Software Edition and Training Session

After Angel Sound program, please click the button in the middle of the screen which is shown as follows to start the training. Note that you can simply use the program with this option only. All the training data and testing data will be saved in the local PC database. If you want to share the data with friends or audiologist, you can use the following "remote server" option. All the data in the local PC database can also be synchronized with remote server for better data sharing and access. The latest version (5.08.03) also allows the remote server login, which allows the user to save the training and testing results at central server. With remote server, the users can access the training and testing data from any computers at any time. To use the remote server login, click the button "Internet Edition Login" in the bottom of the welcome screen. After that, a login window will pop out, the user need to type the account name and password to login their own account. The user is also allowed to create a free new account at any time by clicking the link in the bottom of the remote login window or go to the following website (http://angelweb.emilyfufoundation.org/). For the demo purpose, the user can use the temporary account (demo) and password (1234567) to try the remote login function.

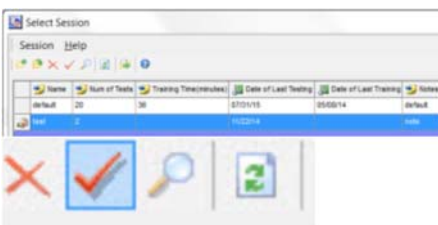| Option 1: Local Edition	Option 2: Internet Edition
Please click the following button in the screen. Note this option is recommended for typical user.	Please click the following button. Note that this option is recommended for audiologists or researchers (data sharing).

After entering Angel Sound program, a session window will pop out. Double click on any of the previous Sessions to open that Session. You can also create a new Session by clicking on the "New" button, and then name and save the new Session. Here is the instruction about session selection.
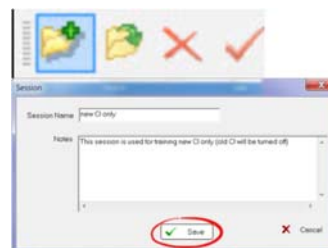
| Option 1: Select Existing Session	Option 2: Create NEW Session
• Choose the session you want to use; • Select the Session by clicking the button from toolbar or menu.	• Click "NEW" button from toolbar or menu. • Input name (any) and note (optional), then Click "Save" button.

2.3 Training Modules and Groups

After selecting the session, the program enter into a module selection stage. All the available modules will be shown in the screen. The module with line border is the one you have used in the last time. You can continue to use the previously used module or select a new module to train. Please click the image in the screen to select the appropriate module.

The first step of using Angel Sound is to select an appropriated training module based on individual speech recognition performance. While an appropriate training module according to individual performance should be selected, any module can be selected regardless of speech recognition performance. For example, adaptive speech in noise module or comprehensive music module can be selected even for the poor-performing users. Also, the users are recommended to switch to different module periodically for better attention.
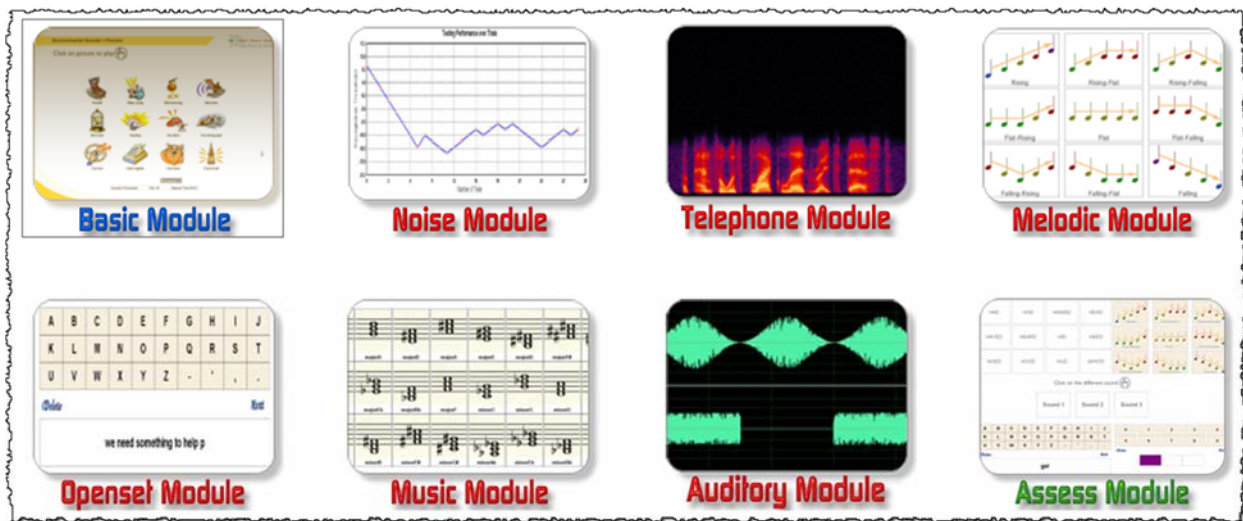
Once the Module is loaded, you can select a Training Group. Each Module contains several Training Groups listed on the left side of the screen (The following shows the screenshot of training groups in the Basic, Openset, Music, Auditory, and Assess Module). Click on one of the Training Groups. The Group name will appear along with several selectable headings.

2.4 Preview Training Test & Results

There are four activities for each Training Group: Preview, Training, Test, and Results.

INTRODUCTION PREVIEW TRAINING TEST RESULT

Preview Tasks

Preview allows you to listen to the sounds you will hear during Training or Testing. Click on the Preview heading, and a list of the sounds will appear. Click on any item, and the sound will play. There are usually several pages of sounds to preview Click on the Forward or Back buttons to move between pages. Click the Stop button to exit Preview.

For newly implanted users or hearing aid wearers, previewing all sound materials may be one of most effective approaches to familiarize all kinds of sounds since sounds with electric stimulation or amplification may be dramatically different from those you are familiar with before. Preview allows you to hear all those familiar sounds again even though some of them (or most of them) are very different. That is why appropriate auditory training is important to improve speech recognition performance for people with cochlear implants or hearing aid. Here are the recommended sound materials for preview. Audio materials include over environmental sounds, monosyllabic words, everyday Sentences, animal, food, family, color, time & number.

Training Tasks

Training helps you to discriminate and identify different sounds. During Training, you will be asked to identify a sound, followed by auditory and visual feedback. Click on the Training heading, and a number of Levels of difficulty will appear. One of the Levels will be underlined as the recommended practice level. Click on a Level to begin Training. After each sound is played follow the instructions about how to respond (e.g., "Click on the different sound," or "Click on the matching sound"). After each response, you will get either visual feedback ("Correct"), or auditory and visual feedback ("Incorrect," with highlighted playback of your response and the correct response). Your results will be displayed at the end of the Training session.

Test Tasks

Each training group has its own testing task. Once selecting a training group (such as vowel recognition group in basic module), five different task buttons will be shown in the screen.

Click the TEST button, the program will perform the corresponding speech recognition test according to the training group. For example, vowel recognition test is shown as follows:
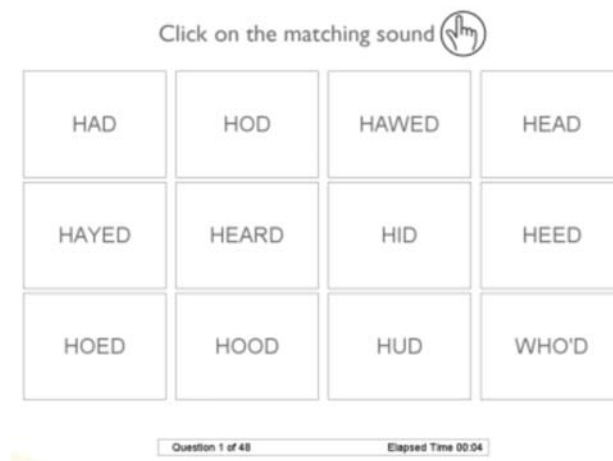
Test monitors your progress and adjusts the difficulty for training. You should periodically test your performance without the feedback. Click on the Test heading, and the test will begin. A sound will be presented and the response choices will be displayed. Follow the instructions about how to respond (e.g., "Click on the different sound," or "Click on the matching sound"). No feedback is given during a Test session. Your results will be displayed at the end of the Test session.

Results View Tasks

Result contains all the Test and Training results within the selected Training Group. As you complete different Training exercises and Tests, the results are automatically saved. Click on the Result heading to display a graph and text description of your Training and Test results. Results may be printed by clicking on the "Print This Page" button. You can click on the Levels headings above the graph to access more detailed information.

2.5 Hints and Tips

It is understandable that the training schedule has to fit your personal schedule. But it is also important to perform sufficient training within a short period to maximize the training benefit.

You can structure your practice sessions however you like but we recommend that you initially spend 30-60 minutes per day, 5 to 7 days per week, on the building blocks of listening—pure tones, consonants, vowels and words. If you take the Auditory Assessment first, you will be placed in the listening program according to your individual skill level. You can try any of the other Levels and Modules at any time. Ultimately, you are in control of your progress.

Monitor display: For optimal screen clarity, set the screen resolution to 1024 x 768 or higher. To set the screen resolution, go to the Start Menu, select Settings, then Control Panel, then Display; the Display Properties dialog will appear. Click on the Settings tab, and move the screen resolution setting to be 1024 x 768 or higher. Alternatively, you can access the Display Properties by right-clicking on the Desktop.

Listen to Angel Sound: You can use either your computer speakers or your TV/Hi-Fi cable to listen to Angel Sound. Be sure to listen in a quiet place, especially if you are using computer speakers.

Listening with computer speakers: If you use computer speakers, set the speaker volume to a comfortably loud level and set the tone (if available) to be flat. Use the sound processor settings you use for every day, quiet listening environments.

Listening with TV/Hi Fi cable: The TV/Hi-Fi cable provides a direct connection between the computer soundcard and your sound processor, thereby eliminating environmental noise while you practice. Be sure to use the appropriate cable for your specific sound processor. Follow these steps:
- Turn off your processor.
- Make sure the TV/Hi-FI cable volume is set to 0.
- Connect the cable to the soundcard output. For many computers, the output is marked with a picture of headphones.
- Connect the other end of the TV/Hi-Fi cable to the audio input on your sound processor. Depending on the sound processor, you may need to use an adapter to make this connection. Refer to your sound processor owner's manual for additional information regarding audio input.
- Select the sound processor program and settings you normally use in quiet listening environments.
- Turn the soundcard volume to near maximum. Usually, there is a speaker icon on the tool bar. Click on this icon and move the volume slider to near maximum level. Alternatively, there may be buttons on the keyboard to adjust the volume.
- Select a module from Angel Sound. Click on the Preview button. Click on a sound and slowly increase the TV/Hi-Fi cable volume to a comfortable level.

Keeping track of your progress: Angel Sound automatically keeps a record of your results for each Training Group within each Module. Results are organized by session names. You should occasionally print your results to keep a record of your progress. We recommend that you share the results with your audiologist and/or auditory therapist. You can print detailed results within each Training Group or a summary of all Training Groups ("Report").

To print a summary Report, select the desired Session and click on Print. The Angel Sound Training Print dialog will appear. Check the items you would like to print, and then click OK.

You may also want to print the "Learn More" files that explain Angel Sound's Test and Training procedures for your clinician or therapist. Click on the Learn More button and the Help file will open. Select a topic from the left column. Once the topic is displayed, right-click on the document and select Print. You can do this for any Learn More topic.

2.6 Frequency Asked Questions

Details regarding the different training exercises and tests can be found by clicking on the Learn More button on the upper right side of the screen. Also, if you have problems using Angel Sound Training Program, check below for troubleshooting tips and solutions to common problems.

What is a Session?
In Angel Sound Training (AST), all the test and training results for any Training Group and Module are stored within a Session. Think of a Session as a "user" When you load a Session, all the user's previous results are available. New results for the user will be appended to the Session automatically. You can create up to five different Sessions. If you are a bilateral implant user and you use AST to practice each ear separately, you might name one Session "Left" and the other "Right."

AST will automatically load the most recently opened Session. Once you open a Session, AST is ready to be used. You can Test, Train, open a different Module, or view and print results. If you want to open a different Session, click on the SESSION heading and the Session window will open; click on the desired Session from the list. To create a new Session, click on the New icon and the New Session dialog will appear; enter the new Session name.

What is a Module?
AST consists of many test and training Modules that contain the various exercises. By default, AST will load the Basic Training Module. If you want to try other Modules, click on the Advanced Modules heading; the Advanced Module Management dialog will open. A list of all Modules will be displayed, and the currently active Module will be indicated. To load a different Module, click on the Module and a new set of Training Groups will appear.

What is a Training Group?
Each Module contains a number of Training Groups. Each Training Group contains the sounds and exercises you will use for training and testing. Each Training Group also contains a Preview function to audition the sounds. After clicking on a Training Group, the headings "Introduction," "Preview," Training," "Test," and "Result" will appear in the Third Row. Click on any of these headings to continue.

How can I preview sounds?
After opening a Training Group, click on the Preview heading. A number of images will appear on screen. Click on any image and the corresponding sound will be played. Some Training Groups have many sounds. You can access different pages by clicking on the Forward or Back Buttons. Click the Stop button to exit Preview.

How does the training work?
Within each Training Group, there are a number of exercises and levels of difficulty. For some Training Groups, the lower levels of difficulty involve discriminating between sounds. As discrimination improves, the contrast between sounds is reduced. After an incorrect response, auditory and visual feedback is given so you can compare your answer to the correct answer.

Once you have learned to discriminate sounds, you will learn how to identify sounds. A sound is presented and you must choose from among several response choices. Again, if you answer incorrectly, auditory and visual feedback is given. As you advance, the number of response choices may be increased and/or the contrast between response choices may be reduced. For the most difficult tasks, sounds are presented with competing background noise. The Advanced Modules offer even more difficult listening tasks like open-set sentence recognition in noise. After you assess your performance with a Test, AST will automatically recommend a Level of difficulty. However, you may try any Level you would like.

How often should I take a test?
Testing is a good way to monitor your progress. In AST, there is no feedback during a test and some of the sounds may be different than those used for training. AST uses the Test results to recommend future levels of difficulty for Training. The tests are generally short. You should test your performance after every 5-10 training exercises.

What do the results mean?
The graph shows your Test results over time since you began training. This why you should regularly test your performance. The table shows the number of training exercises and total time spent training for each level. The Initial Assessment Score shows your performance on your first test. The Final Assessment Score shows your performance for your most recent Test. The Improvement After Training shows the difference in performance between the First and Final Assessment Scores. You can print these Results by clicking on the Print This Page Button. You can see detailed results, including Training and Test summaries and the Test Matrix by clicking on one of the Levels of Difficulty.

What does the "Speed" button do?
The Speed button provides real-time adjustment of the speaking speed for the training sounds. To adjust the speaking rate, click on the Speed button; the Time-stretching dialog will appear. Enable the Real-time Stretching Function. Use the slider to adjust the speaking rate. Note that the values will change as you move the slider (100 = no adjustment; <100 = slower speech; >100 = faster speech). Note that using the Real-time Stretching Function may slow down AST; if so, disable the Real-time Stretching Function. Also, extreme settings may result in an unnatural sound.

What does the "Volume" button do?
The Volume button adjusts the sound card output from within AST. Click on the Volume button; the Set Sound Volume dialog will open. Adjust the sound level using the slider. If you want to use this level for other training exercises, enable the Set Current Volume as Today's Default. In general, it is best to leave this setting at or near maximum. Note that the volume setting does not change the volume control setting on the speaker or the volume control setting on the TV/Hi-Fi cable.

2.7 Troubleshooting

Details regarding the different training exercises and tests can be found by clicking on the Learn More button on the upper right side of the screen. Also, if you have problems using Angel Sound Training Program, check below for troubleshooting tips and solutions to common problems.

Problem — I cannot hear any sound.
Try the following:
- Check that the speakers are connected properly and powered on
- Check that the computer volume is not muted (click on speaker icon in the toolbar)
- Check that the sound card is working properly (Go to Start Menu/Settings/Control panel/Settings/Sounds and Audio Devices and look to see if the correct audio hardware is selected and working)

Problem — I cannot activate AST.
Try the following:
- Make sure you are connected to the Internet during the first time use.

Problem — Screen looks distorted or smeared.
Try the following:
- Be sure the screen resolution is 1024 x 768 or higher.
- Right-click the mouse button and select "Refresh Screen."
- Quit and restart AST or, if necessary, reboot the computer and restart AST.

Problem — AST runs very slowly; the sound is intermittent.
Try the following:
- Make sure your computer meets the minimum system requirements.
- Shut down all other programs except AST to free up memory
- Reboot the computer and restart AST.

Problem — AST doesn't look like the last time I used it. There are different Training Groups.
Try the following:
- Make sure you have selected the correct Session name (go to the Session heading)
- Make sure you have selected the correct Module (go to the Modules heading)

CHAPTER 3 ADVANCED FEATURES

3.1 Configurable Settings

Angel Sound™ is an open platform for auditory rehabilitation. With simple configuration, Angel Sound can be used for different language, different sound materials (pure tones, environmental sounds, words, sentences, music etc) and different listening environments (quiet, noise). Currently, there are one basic module and six advanced modules in Angel Sound according to the features of different sound materials and training requirements. Each module has several default training configuration for specific purpose. Latest version (Version 5.05.01 or higher) allows the user to modify the training configuration based on the default setting and save the new training configuration as the individualized "default" training setting. Here shows the step-by-step instructions:
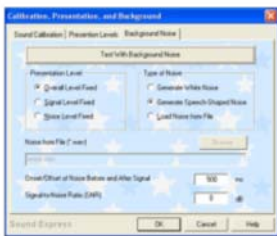
Setting #1   **Noise and Presentation Levels (Ctrl+Alt+F8)**

Angel Sound can generate any noisy speech to mimic the real listening situations based on the quiet, clear speech signals. After starting the training or testing tasks, please press (Ctrl+Alt+F8). The "Calibration, Presentation, and Background" dialog will pop out. Select the "Background noise" tab in the dialog. You will be able to set the noise type and the desired signal-to-noise ratio. You can also use the external sounds or music as the background noise. if you think that the current task is too task, it is the perfect approach to increase the difficulty of the task.

Setting #2   **Setting #2: Sound Selection (Ctrl+Alt+F9)**

The program allows the user to change which sounds in the database will be used for training based on the categories specified in the configuration file. For example, you can only select the STOP consonant in the phonetic contrast training, or one particular talker etc. For the Phonetic Contrast Training, each word will be coded with four distinct categories (initial consonant, medial vowel, final consonant, and talkers). The default setting is that all the words will be included in the training set. However, the user can select the desired tokens to focus on one specific subset of phonemes.
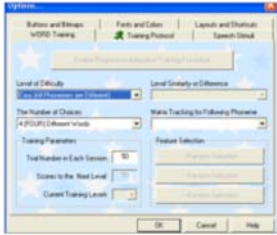
Setting #3   **Visualization and Options (Ctrl+Alt+F10)**

There are six different control panels in the visualization and option window, including Word Training, Training Protocols, Speech Stimuli, Bitmaps, Fonts/Colors, and Layouts. Each panel has several different controls or features. Some of the features are interconnected. For example, the number of choice in the Word Training panel is related to the Rows and Columns value in the Layouts/Shortcuts panel. Basically, Rows x Columns should be same as or larger than the number of choices specified in the WORD training panel.

Setting #4   **Cochlear Implant Simulation (Ctrl+Alt+F6)**

After starting the training or testing tasks, please press (Ctrl+Alt+F6). The cochlear implant simulation dialog will pop out. Enable "Noise or Sinewave Vocoder Processing" and set the appropriate speech processor parameters and click "OK". During this training or testing session, the sound you hear will be processed by the speech processor. This is an excellent tool for normal-hearing listeners to understand how the speech may sound with device.

Setting #5   **Generate Noisy Speech with Various Background Noise**

Another good feature for Angel Sound Program is that the program can generate any noisy speech to mimic the real listening situations based on the quiet, clear speech signals. Again, after starting the training or testing tasks, please press (Ctrl+Alt+F8). The "Calibration, Presentation, and Background" dialog will pop out. Select the "Background noise" tab in the dialog. You will be able to set the noise type and the desired signal-to-noise ratio. You can also use the external sounds or music as the background noise. if you think that the current task is too task, it is the perfect approach to increase the difficulty of the task.

Setting #6   **Control the Sound Source by Using Stereo Setting**

In real life, sounds come from all over the place. This function allow the user to control where the target speech and background noise come from. Press click the "Stereo" button in the right bottom of the screen (See left figure, panel #2). A Stereo Setting dialog will pop out. There are four options, including mono output, stereo output with speech in left, right, or random. Of course, two speakers setting are required for using this function.

Setting #7   **Control the Speaking Rate and PITCH**

In real life, people speaks at very different speaking rate. Someone speaks very fast while others talks very slowly. It is important to understand speech at all these situations. This function allow the user to control the speaking rate of the speech. Press click the "Speed" button in the right bottom of the screen (See left figure, panel #3). A dialog will pop out. The normal speed is 100, which is the speaking rate of the original recording (typical speed). 50 means that speaking rate is 2 times slower while 200 means that the speaking rate is 2 times faster. Also, different speakers have different spectrum due to the difference in vocal tract. This function also allows the user to adjust the pitch of the speech signals. The normal pitch is 100. 50 means that the spectrum is downshifted by one octave. 200 means that the spectrum will be upshifted by one octave. The speaking rate and pitch can be set as a fixed level or can be randomly set in the given range.
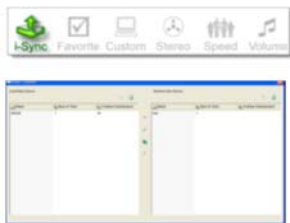
Setting #8   **Data Synchronization between Local and Remote Server**

It is very easy to synchronize the training and testing data between local and remote server. After the program is running, login to the remote server using your account name and password. Click the "Sync" button in the right bottom of the screen (See left figure, panel #1). A new data transfer window will pop out. Click the Sync button in the middle to synchronize all the data or any specific session between local and remote server. Note that version 5.03.01 and an existing account is required for database synchronization function.

Setting #9   **Customized Setting for Individual Training**

While the default configuration in each training module and group is based on the particular feature and training purpose, the latest version also allows the users to modify the default configuration and save the NEW file as the individualized "default" configuration. Click the "Custom" button in the right bottom of the screen (See left figure, circled image). A customized training setting window will appear. Click the button in the middle of the window to save the current (modified) configuration as the NEW configuration file. Note that this button is only enabled when the program detects some changes in the configuration. Otherwise, this button will be disabled.

Setting #10   Custom Sound Volume Controls

The program automatically set the system sound level to the maximum in the default setting. The RMS level of sounds is fixed at 65 dB (digit form) in the default setting. If the sound is still too soft, the user generally can use the external speaker to amplify the sound level. If there is no external speaker, the maximal sound level is dependent on the computer setting. Some laptop computers may have relatively low sound volume even with the system volume setting is maximized. In this case, one possible solution is to increase the RMS levels of sounds (digit form). The current default setting is 65 dB. This function allows the user to modify (mostly increase) the RMS level of signals to make sound louder. To avoid the peak clipping, the maximal value is limited to 85 dB. To modify the volume, click the "Volume" button in the right bottom of the screen. Enable and specify the desired value of RMS level.

Setting #11   Favorite Management Controls

The program allows the users to save their favorite training or testing tasks into the FAVORITE folder. To save the task into the Favorite folder, start the task as normal procedure, then click the "Favorite" button in the right bottom of the screen (see Left Top Figure). The Favorite Management window (see Left Bottom Figure) will appear. Enter the Alias name for the current task and Click the button in the middle to save the current training or testing task into the Favorite List. To run the favorite task, click the "Favorite" button at any time, choose the desired training task in the Favorite List and Click the "Run Favorite" in the left bottom of the window or simply double click the training task in the Favorite List to Start the training. The user can easily delete the training tasks in the Favorite List or Change the Alias name in the favorite list by simply choose and click the "Delete" button in the middle bottom of the screen. The Favorite Management allow the user to perform various training or testing tasks across different modules.

3.2 Examples of Customized Training

While most of training and testing tasks in Angel Sound™ is based on the external configuration, the implementation of such configuration is tedious due to the stimulus specification and graphic integration. However, Angel Sound does allow the user to temporarily customize the training or testing tasks within the specified tasks by using configurable settings. Here are some examples of using configurable settings to change the difficulty of the training or testing tasks.

Example 1: Implement the Self-Defined Repeats after Wrong Choice

Step 1:   Choose the targeted training module, group and levels;

Step 2:   Click Right Mouse Button (Panel 1, below) (or Press CTRL+ALT+F10), Visualization and Option window will appear (Panel 2, below).
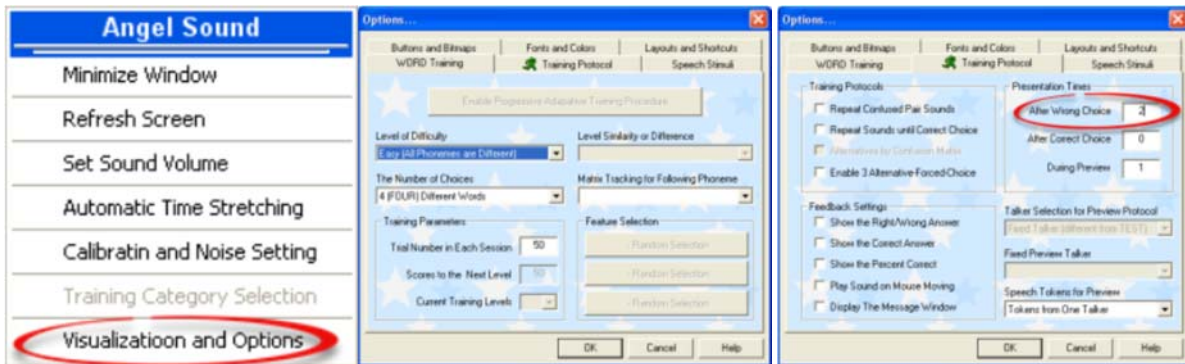
Step 3:   Click the "Training Protocol" panel (Panel 3, above) and modify the value in the "After the Wrong Choice". Then click OK button to complete the change.

Step 4:   Click the "Custom" button in the right bottom of the screen.

Step 5:   Click the button in the middle of the customized training setting window to save the new configuration file as the "default" training setting.

Step 6: Re-start the training level again, new configurable setting will be loaded. To restore the pre-defined default setting, simply click the "delete" button in the customized training setting window.

Example 2 – Focus Training of the six STOP consonants

Step 1: Choose the targeted training module, group and levels. Here uses the BASIC module >> Consonant Training >> Level 5 As the example. Here are four original choose options (Panel 1, below).
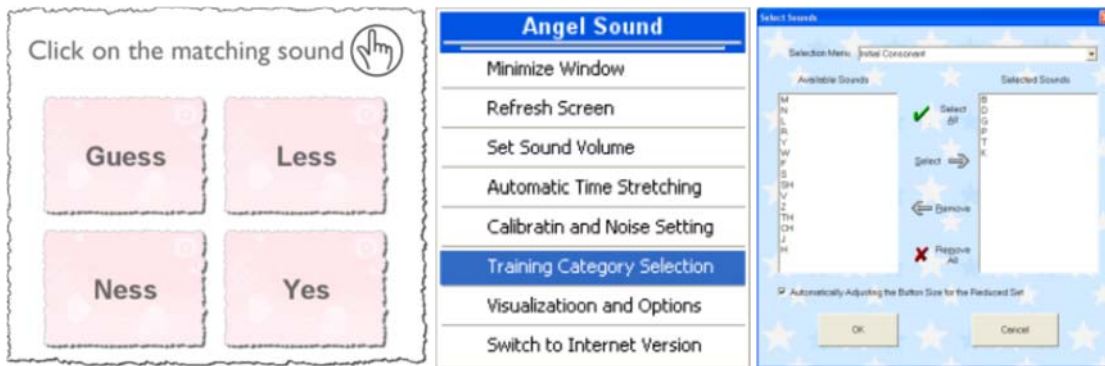
Step 2: Click right mouse button (Panel 2, above) (or Press CTRL+ALT+F9), Sound Selection window will appear (Panel 3, above). Select B, D, G, P, T, K only in the Initial Consonant Section.

Step 3: Click right mouse button again (Panel 1, below) (or Press CTRL+ALT+F10). Click the "WORD Training" panel (Panel 2, below) and modify the value to SIX in the Number of Choice option and meanwhile click the "Enable Progress Training Procedure" button to unselect it (Otherwise, the number of choice will be fixed at four based on the pre-defined adaptive procedure). Then Click the "Layouts and Shortcuts" Panel, change the "Columns" value to 3 while keep the "Rows" value at 2 (Panel 3, below). Then click OK button to complete the change.
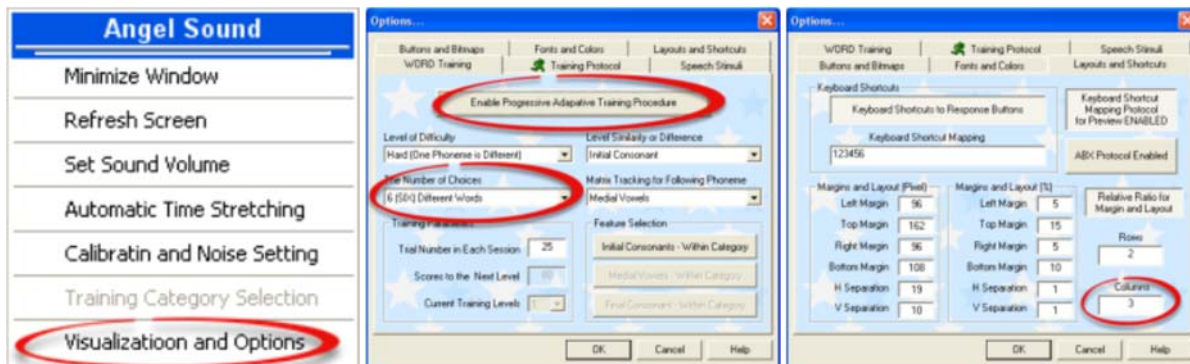
Step 4: Click the "Custom" button in the right bottom of the screen and then click the button in the middle of the customized training setting window to save the new configuration file as the "default" training setting.

Step 5: Re-start the training level again, new configurable setting will be loaded. NEW six choice options are shown as follows. The same procedure can be applied to any other subset of database.
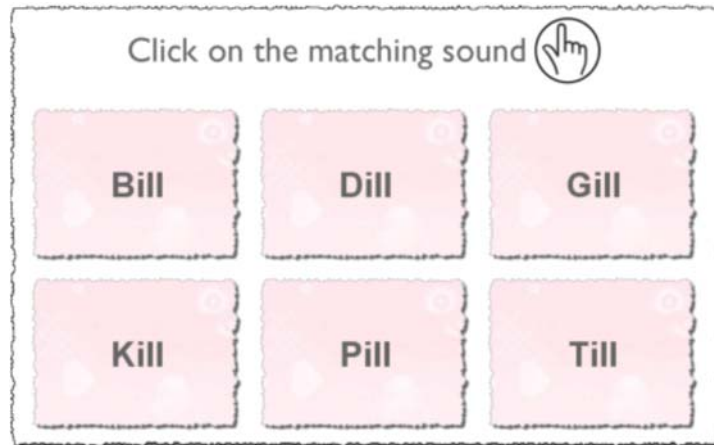
Example 3 – Reducing the Selections in Melodic Contour Identification Test

Melodic Contour Identification (MCI) testing and training module provides a unique way to assess and improve CI listeners' ability to perceive musical notes. The original design contains nine distinct patters, including rising, rising-flat, rising-falling, flat-rising, flat, flat-falling, falling-rising, falling-flat, falling. Angel Sound also allows the user to modify the number of contour patterns in the testing and training. Here is the example of changing the number of contour patterns to 3 (falling, flat, rising) in the 1-semitone training.

Step 1: Choose the targeted training module (Melodic Module), group (Piano) and levels (1 Semitone). Here are four original choose options (Panel 1, below).

Step 2: Click right mouse button (Panel 2, above) (or Press CTRL+ALT+F9), Sound Selection window will appear (Panel 3, above). Select Rising, Flat, and Falling only in the Main Token Section.

**Step 3:** Click the "Custom" button in the right bottom of the screen and then click the button in the middle of the customized training setting window to save the new configuration file as the "default" training setting.

Step 4: Re-start the training level again, new configurable setting will be loaded. NEW six choice options are shown as follows. The same procedure can be applied to any other subset of database.
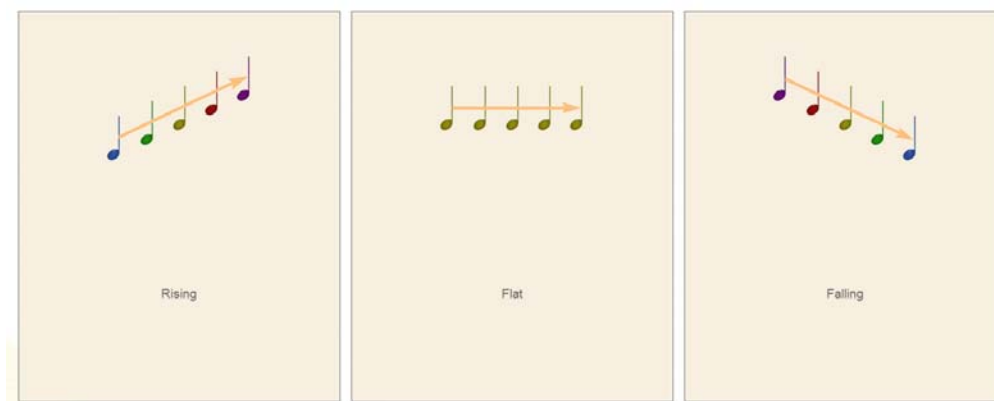
Example 4: Add Customized Background Noise to Training or Testing

Most of training and testing will be done in quiet. Some training tasks are focused on speech recognition in noise. However, most of speech recognition in noise is using either speech-shaped noise or speech babble. Angel Sound allows the user to specify their own background noise (or music) and signal-to-noise ratio. Here is the example of adding music as background noise in vowel recognition training.

Step 1: Choose the targeted training module (basic), group (vowel recognition) and levels (level 3). Here is the screenshot of two original choose options shown in the screen. The stimulus will be presented in quiet.

Step 2: Click Right Mouse Button (Panel 1, below), Calibration and Noise Setting window will appear (Panel 2, below). First, enable "Test with Background Noise". Second, select the Background Noise Tab. Third, select "Load noise from file" option in the Type of Noise. Fourth, click the "Browse" and choose the noise file you want to use (Note that the length of noise files should be longer than speech files. Noise file should also have the same sampling rate as the speech files). Last, change the Signal-to-Noise Ratio as needed. The less the value, the noisy the noisy speech.
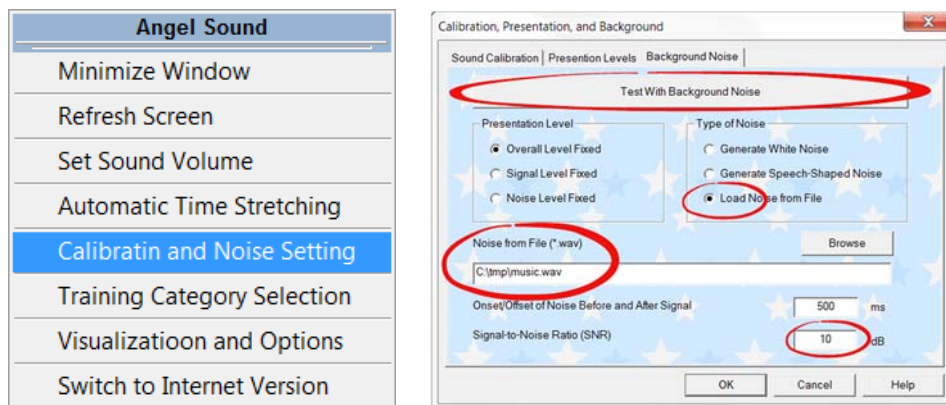
Step 3: Click the "Custom" button in the right bottom of the screen. Click the button in the middle of the customized training setting window to save the new configuration file as the "default" training setting.
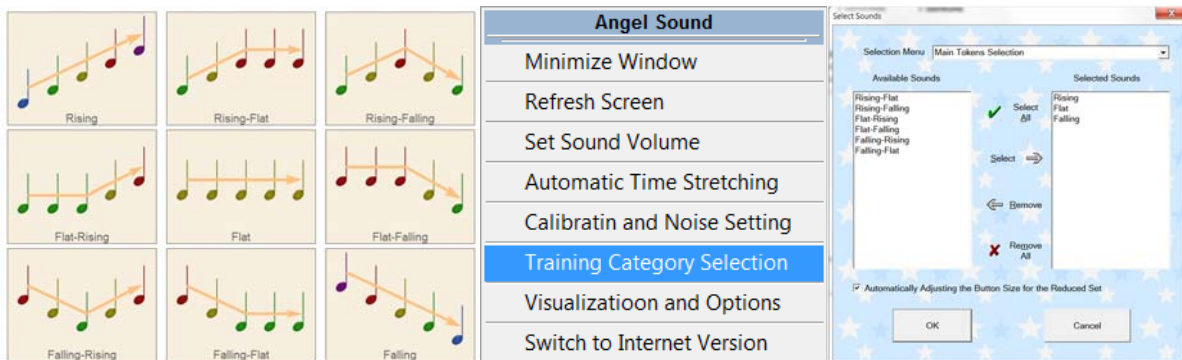
Step 4: Re-start the training level again, new configurable setting will be loaded. To restore the pre-defined default setting, simply click the "delete" button in the customized training setting window.

Example 5: Increasing the Difficulty by Changing Pitch or Speaking Rate

Angel Sound provides over 10,000 originally recorded sound tokens. Sound tokens can be further expanded by using real-time pitch and/or speaking rate adjustment. Here is the example of modifying the speaking rate and pitch in vowel recognition training.

Step 1: Choose the targeted training module (basic), group (vowel recognition) and levels (level 3).

Step 2: Click Right Mouse Button (Panel 1, below), Automatic Time Stretching window will appear (Panel 2, below). Enable both Real-time Time and/or Pitch Stretching. Change the value as needed. Note that 100 refers the original speaking rate or pitch. A value of 200 equals to doubling the speaking rate or pitch. If you want to increase the uncertainty of the stimuli, enable the random rate (pitch) during this range. The program will randomly select a specific rate or pitch at each trial.

Step 3: Click the "Custom" button in the right bottom of the screen. Click the button in the middle of the customized training setting window to save the new configuration file as the "default" training setting.
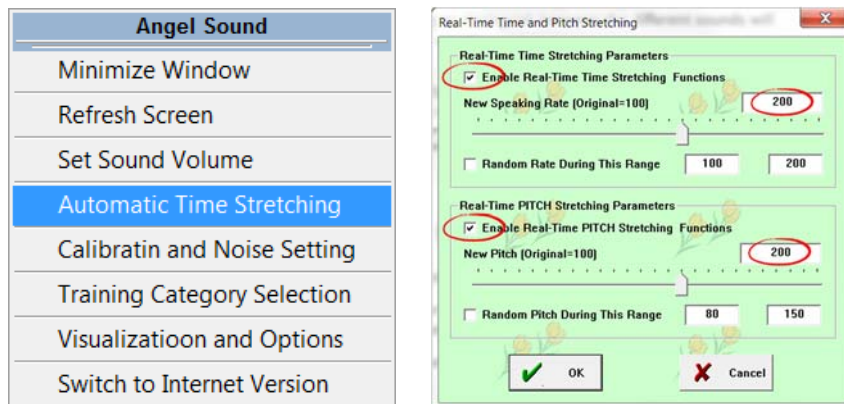
Step 4: Re-start the training level again, new configurable setting will be loaded. To restore the pre-defined default setting, simply click the "delete" button in the customized training setting window.

CHAPTER 4 TRAINING MODULES

Welcome to **Angel Sound**^{TM}, an interactive program that lets you take control of your listening rehabilitation independently at home. You gain practice in discriminating and identifying sounds and speech components through a series of self-paced groups that cover different aspects of the listening process. Each training group presents a range of trials in which you need to match a given sound to one of several images, words or sentences. The level of difficulty is adjusted to match your developing listening skills. The program provides feedback, highlighting areas you can continue to practice. This feedback can be shared with your clinician or therapist, who can provide further advice on your rehabilitation. Focused on practice and improvement of your listening skills, Angel Sound compliments your clinic rehabilitation program. Good luck with your listening practice!

Module #1   **Basic**

Basic Module

Basic module targets very broad range of training tasks, including pure tone discrimination (basic frequency resolution), environmental sounds, voice genders, vowel, consonant, words, and sentence recognition. This module is suitable for new cochlear implantees and hearing aid wearer so they have the chance to familiarize with all kind of sound materials and basic discrimination and identification task.

Module #2:   **Telephone speech recognition**

Telephone Module

This module is exactly same as the basic module except that all the sound materials are bandlimited to the frequency range of telephone speech (300-3200 Hz). After familiar with the basic module, anyone who is interested at improving telephone conversation can try this module.

Module #3   **Melodic contour identification**
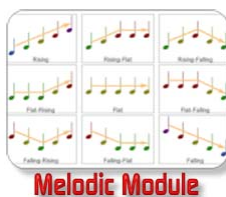
Melodic Module

This is a simple music module which is targeted at melodic contour identification. The difficulty is controlled by semitone between notes and this module also provides midi sounds from several different instruments. Anyone who is interested at improving music appreciation should try this module first.

Module #4   **Adaptive speech in noise**
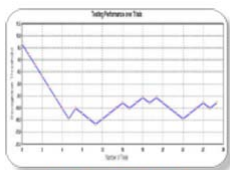
This is an advanced module. In general, the user should perform better than 80% in quiet condition before using this module. All the tasks in this module are using adaptive approach, where the noise level will be adjusted according to the users' response. In general, this module is suitable for good-performing users.

| Module #5 | **Comprehensive music** |
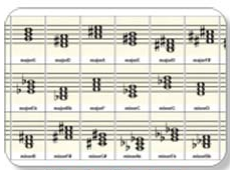
This is an advanced music module which is targeted at various aspects of music appreciation, including basic note discrimination, melodic contour identification, melodic sequence recognition, chord recognition, polyphonic contour identification etc. Many tasks are very difficult so this module is generally suitable for good-performing users.

| Module #6 | **Openset recognition** |

This module is attempted at mimicking the real-life conversation where the user has to recognize the sentences or words without knowing the intended contents or choices by the speakers. In general, this module is relatively difficult and suitable for good-performing users.

| Module #7 | **Auditory resolution** |
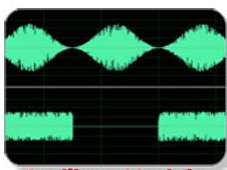
Auditory resolution module is a special module targeted at improving the ability to detect the subtle difference among sounds differed in one specific dimension, such as frequency, temporal, and/or amplitude. Such discrimination ability is the foundation for higher-level speech (phoneme, word, or sentence) recognition. Auditory resolution module is suitable for all users.

| Module #8 | **Functional Hearing Test** |

It is important to use appropriate functional hearing test to assess whether hearing-impaired people benefit from their cochlear implant or hearing aid. Most well-known standardized function hearing tests are openset sentence or word recognition. However, openset recognition tasks are difficult for hearing-impaired people to administer at home alone since these tasks generally require third-party to perform. One of the powerful features in the Angel Sound is the seamless integration of speech training and testing function.

4.1 Basic Training Module

Basic module targets very broad range of training tasks, including pure tone discrimination (basic frequency resolution), environmental sounds, voice genders, vowel, consonant, words, and sentence recognition. This module is suitable for new cochlear implantees and hearing aid wearer so they have the chance to familiarize with all kind of sound materials and basic discrimination and identification task.

Group 1: Pure Tone Discrimination

Purpose: In this group you gain practice in discriminating between different tones. These are the same tones you will have experienced in your mapping sessions. As well as making future mapping sessions easier, this may help your ability to hear differences in the pitch of sounds, a good starting point in developing your language recognition skills. Pitch adds melody to the spoken word and sentence, and is a key component to understanding nuances in conversation. Pitch can be most easily thought of as the different notes on a piano. When you press a key on the left-hand side of the piano, you will generally hear a 'low' pitch; when you press a key on the right-hand side of the piano, you will generally hear a 'high' pitch. These pitch qualities will generally hold true, even if the loudness of the sounds change. By listening carefully to the tones during training and testing, you are given a better sense of the different pitches provided by your Cochlear implant.

Methods: 52 music notes (A3-C7) are used in the current group. All levels present discrimination tasks. In each task, three sounds (tones) are played, and their corresponding response buttons highlighted. Two of the sounds have the same pitch, while the other sound has a different pitch. Click on the response button you think has the different pitch. As you move up through the levels of difficulty, the tone comparisons (the differences between tones) become more closely spaced and therefore more difficult to discriminate between. Beginning at level 1, the tone comparisons are widely spaced (10-12 semitones). By level 5, the tone comparisons are the most narrowly spaced (1 semitone). Some tone comparisons may be very difficult, so don't be disappointed if you cannot discriminate all the tones. Panel 1 below shows the 3 responses during training or testing tasks.

A3	A#3	B3	C3	C#3	D3
D#3	E3	F3	F#3	G3	G#3
A4	A#4	B4	C4	C#4	D4
D#4	E4	F4	F#4	G4	G#4

Summary: There are 25 individual trials in each run. There are five training levels in this group, including
- Level 1 (tone separation): 10-12 semitones
- Level 2 (tone separation): 7-9 semitones
- Level 3 (tone separation): 4-6 semitones

- Level 4 (tone separation): 2-3 semitones
- Level 5 (tone separation): 1 semitone

Tip: You can use the Preview button to listen to all the tones before training to get a sense of the pitch range provided by your Cochlear implant.

Group 2: Environmental Sounds

Purpose: In this group you can develop your ability to identify common everyday sounds. Even when speech recognition is difficult, the Cochlear implant can provide important hearing information about the world around you, such as the sound of a bird chirping, a car horn blaring or a doorbell ringing. Being able to associate particular sounds with objects or events in your surroundings, may assist you in developing your auditory memory abilities.

Some users will notice that things that sounded one way before they started using the Cochlear implant, now sound quite different. For instance, the sound of your telephone ringing may be quite different now, possible clearer, higher pitched and so on. In this case you need to associate the now unfamiliar sound with its source. Once you have re-identified these sounds, you can then develop a memory for some of the many, sometimes confusing new sounds you encounter

Methods: The stimuli include 100 environmental sounds. All levels present identification tasks. In each task, a sound is presented and you must choose the response button you think best matches the sound. As you move up through the levels of difficulty, the number of response buttons will increase. Level 1 has two response choices, level 2 has four (Panel 2 below), level 3 has six (Panel 3 below), and level 4 has six response choices along with background noise.

Summary: There are 25 individual trials in each run. There are four training levels in this group, including
- Level 1 (quiet): 2 alternative choices
- Level 2 (quiet): 4 alternative choices
- Level 3 (quiet): 6 alternative choices
- Level 4 (speech-shaped noise, 5 dB SNR): 6 alternative choices

Tip: You can use the Preview function to listen to all 100 environmental sounds. 12 sounds are shown on each page (Panel 1 above) and you can access the next group of sounds by clicking on the Next Page button.

Group 3: Male Female Recognition

Purpose: In this group you can practice your ability to distinguish between the voices of different speakers. Many implant users, even those with good speech recognition abilities, have difficulty telling one voice from another, or even a male voice from a female voice. By concentrating on the quality of a speaker's voice, you may better hear the differences between speakers of different genders and perhaps of the same gender (a more difficult task).

The words used in this module are: had, hod, hawed, head, hayed, heard, hid, heed, hoed, hood, hud, who'd. This limited set of words is used so you can concentrate on qualitative differences between the voices of different speakers, rather than trying to identify the word being spoken. With training, you may better be able to identify the gender of a speaker by the quality of their voice. And being able to more easily recognize who is talking in a conversation may make it easier for you to follow conversations.

Methods: Two different training methods are used, depending on the level of difficulty. Levels 1 and 2 provides discrimination tasks (left panel below). In each task, three sounds (all the same word, spoken by two different speakers) are played, and their corresponding response buttons highlighted. For Level 1, within each trial, a male and a female speaker will each speak the same word (such as 'had'). For Level 2, either two male or two female speakers will each speak the same word. Click on the button you think is the different speaker. Level 3 provides identification tasks. A word is presented and you must choose from among the four response buttons representing the different speakers (male-1, male-2, female-1 female-2). Click on the speaker you think spoke the word (right panel below).

Voice 1	**Voice 2**	**Voice 3**	Female1	Female2
			Male1	Male2

Summary: There are 48 runs in each trial. Stimuli include 12 words spoken by four different speakers (two male and two female). Either discrimination or identification protocol is used in the training or testing. There are three different training levels, including
- Level 1: 3-AFC discrimination with different gender
- Level 2: 3-AFC discrimination with same gender
- Level 3: 4-AFC talker identification

Tips: Try repeating the words you hear in this module, and listen to how your pronunciation compares to the speaker's voice. As children learn language and new words through repetition, practice through repetition within these modules is recommended. You can use the Preview function to listen to all 12 words spoken by each of the four speakers. Compare the four speakers directly by clicking on the same word for each speaker. Listen for any large pitch differences between speakers as you listen to the word.

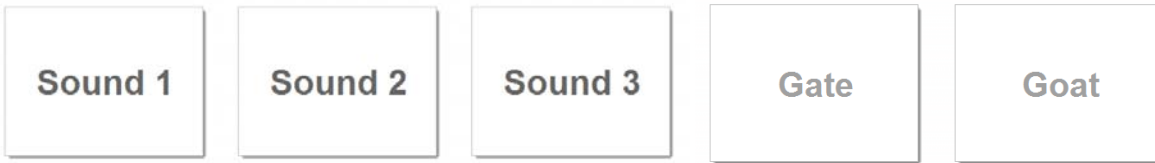|	had	hod	hawed	head
male1	had	hod	hawed	head
male2	had	hod	hawed	head
female1	had	hod	hawed	head
female2	had	hod	hawed	head

Group 4: Vowel Recognition

Purpose: In this group you gain practice in telling the difference between vowel sounds. Vowel sounds provide a great deal of information within speech and are perhaps the most important part of speech. They add emotion and melody to a speaker's voice, as well as subtle changes to the meaning of the words and sentences they use.

By training with many different words (such as cat, kit, cut, etc.) spoken by different speakers, you may better be able to identify vowel sounds. Monosyllable words were chosen so that you can concentrate mainly on the middle vowel sound of each word. Improving your vowel recognition will improve your understanding of words and sentences.

Methods: Several different training methods are used, depending on the level of difficulty. Within each level of difficulty, there are multiple 'steps' that make the training progressively more difficult.
- Level 1 provides simple discrimination tasks (left panel below). You have to listen for difference between sounds, rather than try to identify sounds, which can be much more difficult.
- Level 2 provides a mix of discrimination and identification tasks. You have to compare two words spoken by one speaker, to a third word spoken by a different speaker, with the third word matching one of the two previous words.
- Level 3 provides an identification task (right panel below). Click on the response button you think best matches the presented word.
- Level 4 is similar to level 3, except that more difficult vowel contrasts are presented. As with level 3, an identification task is used. Click on the response button you think best matches the presented word.
- Level 5 is the most difficult vowel training exercise. It is similar to level 4, but the words are played against a background of different amounts of additional background noise. Most implant users, even those who have good speech recognition abilities in quiet listening conditions, have great difficulty understanding speech in noisy backgrounds. Unfortunately, most real-world listening conditions involve some degree of background noise. The noise suppression settings in the speech processor can help to eliminate some background noise, but not completely. By training with speech in noise, you may be better able to separate the words from the background noise. Because word recognition in noise is very difficult, level 5 requires that you are capable of good recognition in quiet listening conditions. Similar to the level 3 and 4 exercises, an identification task is used. A word is

presented in the presence of background noise and you must choose from the response button you think best matches the word.

| Sound 1 | Sound 2 | Sound 3 | Gate | Goat |

Summary: There is 50 run in each trial. Stimuli contain 1163 words spoken by four speakers (two male and two female). Either discrimination or identification method is used in the training and test. There are five different training levels, including

- Level 1: 3-AFC discrimination with 16 different steps of difficulty levels
- Level 2: 2-AFC identification with 16 different steps of difficulty levels
- Level 3: Identification with 16 different steps of difficulty levels, number of response choices increases from 2 to 9 depending on the step number;
- Level 4: Identification (with-category) with 18 different steps of difficulty levels, number of response choices increases from 2 to 9 depending on the step number;
- Level 5: 4-AFC vowel identification in noise (within-category only) with 16 SNR levels

Tips: You can use the Preview function to listen to all 1163 words spoken by each of the four speakers (left panel below). This may be helpful in 'auditioning' unfamiliar words. You can also practice your word pronunciation by clicking on the preview words and comparing them to your own pronunciation. Listen for any general pitch differences that may be helpful in distinguishing words. For example, 'food' might sound low-pitched while 'feed' may sound higher-pitched. You can also use the Test function to assess how well you can identify different vowels (right panel below).

Bab	Babe	Back	Bad	Bade
Badge	Bag	Bait	Bake	Bale
Balk	Ball	Bam	Ban	Bane
Base	Bash	Bass	Bat	Batch

HAD	HOD	HAWED	HEAD
HAYED	HEARD	HID	HEED
HOED	HOOD	HUD	WHO'D

Group 5: Consonant Recognition

**Purpose:** This group develops your ability to recognize differences between consonant sounds. This helps you in your speech recognition, particular since different sounding consonants can have similar lip movements (for example, pat, bat, mat).

Although generally shorter and quieter than vowels, consonants are a very important part of speech. Perhaps you experienced difficulty in hearing soft consonant sounds before you received

your Cochlear implant, which made speech recognition difficult. With the implant, the consonants may be more 'audible', but still difficult to identify. Indeed, consonants are often much more difficult to identify than vowels. By training with many different consonants (such as 'aBa', 'aDa', 'aSa', etc.) spoken by different speakers, you may better be able to identify consonant sounds. This will improve your ability to understand words and sentences.

Methods: Several different training methods are used, depending on the level of difficulty. Within each level of difficulty, there are multiple 'steps' that make the training progressively more difficult.

- Level 1 provides simple discrimination tasks. You have to listen for the difference between sounds, rather than try to identify sounds, which can be much more difficult. Three sounds (two different words, spoken by one speaker) are presented and the corresponding response buttons highlighted. The initial or final consonants are different between the two words, but the middle vowels are the same (for example: 'pass' and 'pack'). Click on the button you think is the different word.
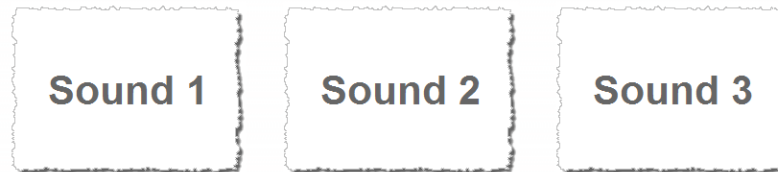
- Level 2 provides a mix of discrimination and identification tasks. You need to compare two words spoken by one speaker to a third word spoken by a different speaker, with the third word matching one of the two previous words. Three words are spoken, two by the same speaker, the third by a different speaker. The words differ only in their initial or final consonant. Click on the response button you think matches the third word.
- Level 3 provides identification tasks (left panel 1 below). A word is presented and you must choose the response button you think best matches the word. The responses differ only in terms of the initial or final consonant.
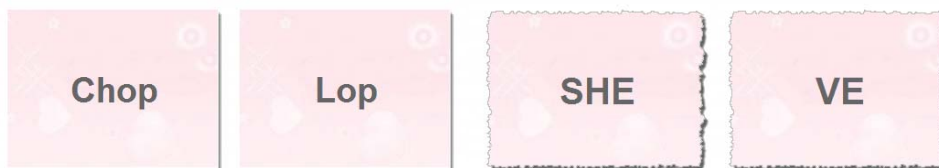
- Level 4 provides identification tasks similar to level 3 (right panel above). in this case tough, more difficult consonant contrasts are used: consonant/vowel (Ba, Da, Sa…) and vowel/consonant/vowel (aBa, aDa, aSa…) words. A word is presented and you must choose the response button you think best matches the word.
- Level 5 is the most difficult consonant training exercise. It is similar to level 4, but the words are played against a background of different amounts of additional background noise. Most implant users, even those who have good speech recognition abilities in quiet listening conditions, have great difficulty understanding speech in noisy backgrounds. Unfortunately, most real-world listening conditions involve some degree of background noise. The noise suppression settings in the speech processor can help to eliminate some background noise, but not completely. By training with speech in noise, you may be better able to separate

the words from the background noise. Because word recognition in noise is very difficult, level 5 requires that you are capable of good recognition in quiet listening conditions. Similar to the level 3 and 4 exercises, an identification task is used. A word is presented in the presence of background noise and you must choose from the response button you think best matches the word.

Summary: Number of trials: 50
Number of stimuli: 5132 in total:

                4652 (1163 consonant/vowel/consonant words by four speakers)
                80 (20 vowel/consonant/vowel words by four speakers)
                80 (20 consonant/vowel by words four speakers)

Number of speakers: two male and two female
Training method: Discrimination or Identification
Training Levels:

- Level 1:3-AFC discrimination with 16 different steps of difficulty levels
- Level 2:2-AFC identification with 16 different steps of difficulty levels
- Level 3:Identification with 16 different steps of difficulty levels, number of response choices increases from 2 to 9 depending on the step number;
- Level 4:Identification (with-category) with 18 different steps of difficulty levels, number of response choices increases from 2 to 4 depending on the step number;
- Level 5: 4-AFC consonant identification in noise (within-category only) with 16 SNR levels

Tips: You can use the Preview function to listen to all 60 consonants spoken by each of the four speakers (left panel below). This may be helpful in 'auditioning' unfamiliar consonants. You can also practice your consonant pronunciation by clicking on the preview words and comparing them to your own pronunciation. Listen for any general pitch, loudness or duration differences that may be helpful in distinguishing consonants. For example, 'aSHa' might sound fairly loud and long and somewhat high-pitched, while 'aWa' may sound relatively quiet, short and low-pitched. Remember that consonant recognition is one of the most difficult challenges for implant users; don't be discouraged and know that the context of sentences and words may help you understand consonant sounds when absolute identification is too difficult. You can also use the Test function to assess how well you can identify different consonants (right panel below).

Boon	Boot	Booth	Booze	Bop		aBa	aDa	aGa	aPa	aTa
Boss	Bot	Botch	Both	Bought		aKa	aMa	aNa	aLa	aRa
Bowl	Buck	Bud	Budge	Buff		aYa	aWa	aFa	aSa	aSHa
Bug	Bull	Bum	Bun	Burg		aVa	aZa	aTHa	aCHa	aJa

Group 6: Word Discrimination

Purpose: This group helps you to listen to common words used in everyday speech, including words for animals, foods, colors and so on. Like other modules, repeating the words and comparing your pronunciation to that of the speakers is an excellent way to practice.

The Word Training module differs from the Vowel Recognition module, in that words are organized according to a category or general theme (Animal, Food, Color, Family, Number, Time), instead of strictly according to acoustic similarities and differences. In the Word Training module, you will build a vocabulary of words (one, two or more syllables), as opposed to training to hear only small differences between words. Some of the words you may have heard before, some you may not. With training, you will be better able to understand some of the commonly used words and phrases you may encounter in everyday life.

Methods: The Word Discrimination module is not progressive - unlike the Vowel or Consonant Recognition modules there are no increasing levels of difficulty. For all training exercises, a simple identification task is used. A sound is presented and you must choose the response button you think best matches the sound.

Summary: There is 25 trials per run. Stimuli contain 100 words from six categories spoken by four different speakers, for a total of 2400 words. There are four response choices for all training and testing. Here are the six categories used in the training: animal names, food names, colors, family, number, time & date)

| Chalky | Sandy | Heir | Mom | 42 | 51 | Decade | Martin Luther King Day |
| Silver | Sky blue | Nephew | Stepchild | 80 | 85 | Rosh Hoshanah | Sunday |

Tips: You can use the Preview function to listen to all 100 words in each category. It is also good practice to compare your pronunciation of the training words to that of the speakers. Also, listen for differences in the number of syllables in the presented word and the response choices.
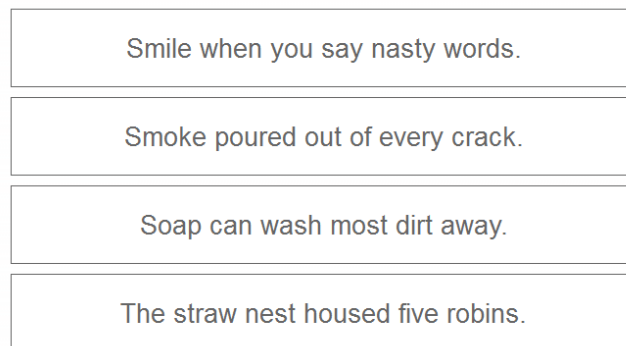
Group 7: Everyday Sentences

Purpose: This group presents typical sentences used in everyday conversation. Your previous experience with word discrimination may help you better hear the words used in the context of a sentence. While you may not hear all of the sentence, you may still be able to fill in the missing parts through hearing words you are familiar with. The more words you can identify the better able you may be in listening to and understanding complete sentences. This group also introduces noise played as a background to the sentence. This is because conversations tend to take place against other competing noises. Developing your ability to isolate the spoken sentence and excluding the background noise is good practice for real-world listening situations. Even

Cochlear implant users who have excellent sentence recognition in quiet listening conditions sometimes have greater difficulty when background noise is introduced.

In the Everyday Sentence training module, you will follow speech in its most natural form, as opposed to identifying isolated words (Word training) or recognizing small differences between words (Vowel or Consonant Recognition training). You may even find it easier to identify the correct sentence from among the four choices than identifying the isolated words, vowels or consonants in the other training exercises. Reading along with the response choices text is very helpful in this regard, analogous to lip-reading. However, without the benefit of lip-reading or text captions, sentence recognition may be very difficult (like talking on the telephone). The Everyday Sentence module will familiarize you with the sounds and rhythms of natural speech.

Methods: All levels provide identification tasks. A sentence is presented and you must choose the response button you think best matches the sentence. There are 4 levels of difficulty:
- Level 1 presents sentences in quiet (no background noise).
- Levels 2 through 4 presents the sentence against increasing amounts of background noise. Level 2 presents sentences that are much louder than the noise. For level 3, the differences in noise between the sentence and background is reduced, And for level 4, the noise is almost as loud as the speech (thus making it more difficult to extract the sentence).

Smile when you say nasty words.
Smoke poured out of every crack.
Soap can wash most dirt away.
The straw nest housed five robins.

Summary: There are 25 trials in each run. Stimuli contain 720 sentences spoken by two speakers, for a total of 1440 sentences. Here are four response choices for each training or test. There are four different training levels, including
- Level 1: No noise
- Level 2: 15-dB signal-to-noise ratio
- Level 3: 10-dB signal-to-noise ratio
- Level 4: 5-dB signal-to-noise ratio

Tips: Try not to look at the response choices before the sentence plays; after the sentence finishes playing, look at the response choices and see whether any of them match your hearing of the sentence. Since all the sentences are lists in the response choices, it is a relatively easy task in terms of speech understanding. If you want to have more challenging tasks in terms of sentence level training, please use open-set training module or adaptive speech in noise training module where an advanced words-in-sentence training protocol is used in those training modules.

Group 8: Music Appreciation

Purpose: This group lets you listen to and compare some common musical instruments and some common melodies. This may be a good place to begin your appreciation of music, or to re-establish your music listening experience.

Many people express different degrees of music appreciation with their Cochlear implant. Some enjoy music and can hear different instruments and melodies, while others do not enjoy music at all. Sometimes, the type of music or listening environment can greatly affect an implant user's experiences.

Methods: The Music Appreciation module is not progressive in that there are no increasing levels of difficulty. For all training exercises, a simple identification task is used. A sound is presented and you must choose the response button you think best matches the sound.

Summary: There is 18 trials in each run. Stimuli contain 9 different instruments and 16 different melodies. There are four response choices for both instrument identification and familiar melody identification during the training.

Tips: Some music and instruments may sound better than others. It can be helpful to watch real musicians play and 'track' their performance. This is somewhat like lip reading, in that it can be easier to understand the melody or instrument if you see how it is being played. Try listening to music with a lot of 'space' between sounds or instruments; music that leaves space for one solo instrument may be easier to follow than an entire orchestra playing at once.
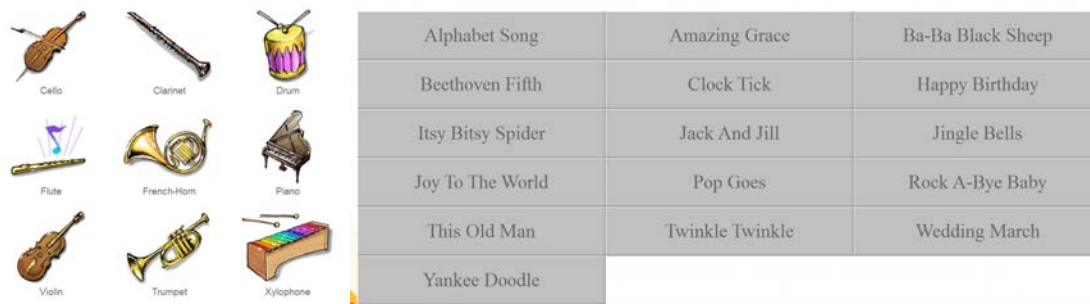
4.2 Telephone Training Module

Telephone speech training module is designed to improve the recognition performance of bandlimited speech (telephone speech). This module is similar to the basic module except that the frequency range of all acoustic sounds is limited to telephone bandwidth (300-3200 Hz). After familiar with the basic module, anyone who is interested at improving telephone conversation can try this module. Here shows the example of original and telephone bandlimited waveform and spectrum.

Waveform and spectrogram of a typical broadband sentence
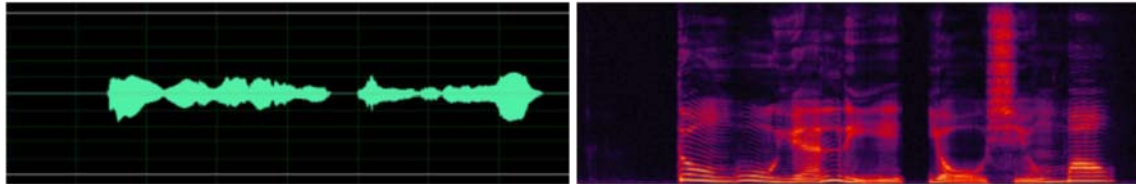
Waveform and spectrogram of a typical bandlimited sentence (telephone speech)
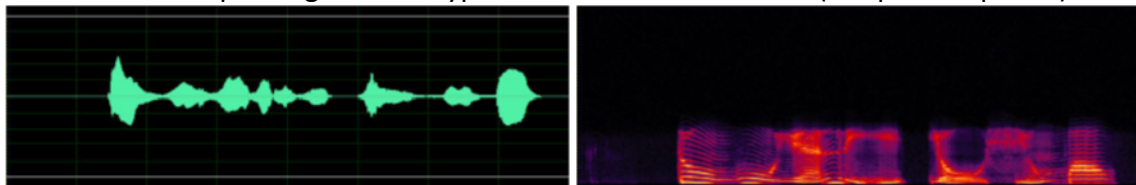
The following explains the difference between telephone speech and broadband speech for each individual training group.

|	
Group 1 	**Pure Tones – practice identifying different pitches** Pure tones within the frequency range of 300-3200 Hz are not affected. Any pure tones out of this range will be severely attenuated. Some listeners may not be able to hear any sounds outside of this range. Some performance degradation is expected with this training group. Since some sounds are highly attenuated, the training is designed to help the listener recognize very soft sounds.
Group 2 	**Environmental Sounds** There will be little change in one's ability to recognize environmental sounds that have limited high frequency components. However, recognition performance of those environmental sounds that include high frequency components will be significantly reduced. It is expected that overall recognition performance will be reduced with bandlimited. The training will help the listener focus on the available spectral cues and discriminate different sounds with limited spectral information.

Group 3
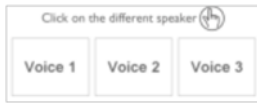
Male/Female Identification-discriminating between speakers

Recent studies have shown that the voice gender recognition can be significantly affected by band limiting (Horng et al., Ear and Hearing, 28(2), Suppl. 66S-69S). Loss of high frequency information weakens the spectral contrast and results in lower recognition performance. The training will aid the listener to focus on the periodicity cue to discriminate voice gender and improve overall voice gender recognition performance.

Group 4

Vowel Recognition - vowel discrimination and identification

Vowel recognition is highly dependent on the F1 and F2 formant frequencies. Since these are within telephone bandwidth, vowel recognition performance is not significantly affected by band limiting for English. However, vowel recognition performance is significantly reduced with telephone speech for other languages such as Chinese. One reason is that some Chinese vowels are dependent on the spectral difference in the high frequency region (e.g., YI versus YU). The loss of high frequency information makes it difficult to discriminate these vowels in the Chinese language.

Group 5

Consonant Recognition

Consonant recognition is highly dependent on high frequency components. The loss of high frequency components in band limiting speech may significantly reduce the recognition performance of consonants. The training will help the listener to utilize other available cues to discriminate different consonants.

Group 6

Word Discrimination

Word recognition will be affected by the loss of high frequency components with telephone speech since words generally include both vowel and consonant segments. Since English vowel recognition is not affected by telephone bandwidth, performance will be more dependent on consonants. Some words will be more affected by band limiting than others. The training will aid the listener to utilize the available spectral cues to discriminate different words.

Group 7

Everyday Sentences

Sentence recognition is one of the listening tasks which will be most affected by band limiting. Recent studies show a near 20% drop in recognition performance with limited bandwidth [Fu, Q.-J. and Galvin, J.J. III (2006). "Recognition of Simulated Telephone Speech by Cochlear Implant Patients," Am J Audiol. 15(2), 127-132]. The training will aid the listener to utilize available spectral cues to understand sentences.

Group 8   **Music Appreciation**

Some musical instruments and familiar tunes may not be affected by band limiting if their frequency ranges are primarily within the 300-3200 Hz. Otherwise, recognition performance will be impacted by the limited band.

4.3 Adaptive Speech in Noise Module

This is an advanced module targeted at improving speech perception in the presence of background noise. This module is appropriate for experienced users to improve speech understanding in background noise. Two advanced training protocols are used: phoneme-in-noise protocol and keyword-in-sentence. The background noise includes six-talker speech babble, speech-shaped steady noise, and white noise. The following shows the spectrogram of different background noise. All procedures use closed-set with 4-alternative choices.

Broadband White Noise	Speech-Shaped Noise	Six-Talker Speech Babble
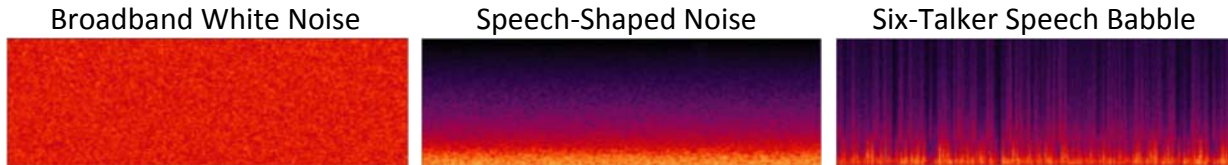
The following describes the six training groups used in this training module.

Group 1   **Adaptive Medial Vowel Recognition in Noise Training**

This training group is similar to the vowel recognition training group in the basic module except that it is performed in the presence of background noise. The signal-to-noise ratio varies according to the response from the subject. If the subject responds correctly, the signal-to-noise ratio is reduced by 2 dB. Each session includes 25 trials and there are four choices in each trial. During each trial, there is one monosyllabic word (initial consonant + medial vowel + final consonant). The initial consonant and final consonant are the same for all four choices. The medial vowel is different for the four choices. A typical example of four alternative choices is: "bat", "but", "bit", "bet". This training group will allow the listener to concentrate on the middle vowel sound of each word in the presence of background noise.

Group 2   **Adaptive Initial Consonant Recognition in Noise Training**

This training group is similar to consonant recognition training group in the basic module except that it is performed in the presence of background noise. The signal-to-noise ratio varies according to the response from the subject. If the subject responds correctly, the signal-to-noise ratio is reduced by 2 dB. Each session includes 25 trials and there are four choices in each trial. During each trial, there is one monosyllabic word (initial consonant + medial vowel + final consonant). The medial vowel and final consonant are the same for all four choices. The initial consonant is different for the four choices. A typical example of four alternative choices is: "cat", "pat", "fat", "rat". This training group will allow the listener to concentrate on the initial consonant sound of each word in the presence of background noise.

Group 3   **Adaptive Medial Consonant Recognition in Noise Training**

This training group is similar to consonant recognition training group in the basic module except that it is performed in the presence of background noise. The signal-to-noise ratio varies according to the response from the subject. If the subject responds correctly, the signal-to-noise ratio is reduced by 2 dB. Each session includes 25 trials and there are four choices in each trial. During each trial, each choice represents one monosyllabic word (initial vowel + medial consonant + final vowel). The initial vowel and final vowels are the same for all four choices. The medial consonant is different for the four choices. A typical example of four alternative choices is: "ubu", "uru", "ufu", "udu". This training group will allow the listener to concentrate on the medial consonant sound of each word in the presence of background noise.
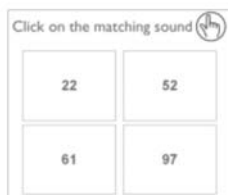
Group 4   Adaptive Final Consonant Recognition in Noise Training

This training group is similar to consonant recognition training group in the default basic module except that it is performed in the presence of background noise. The signal-to-noise ratio varies according to the response from the subject. If the subject responds correctly, the signal-to-noise ratio is reduced by 2 dB. In the other words, the signal-to-noise ratio is increased by 2 dB. Each session includes 25 trials and there are four choices in each trial. During each trial, each choice represents one monosyllabic word (initial consonant + medial vowel + final consonant). The initial consonant and medial vowel are the same for all four choices. The final consonant is different for the four choices. A typical example of four alternative choices is: "bat", "ban", "bag", "bad". This training group will allow the listener to concentrate on the final consonant sound of each word in the presence of background noise.

Group 5   Adaptive Number Recognition in Noise Training

This training group is similar to number recognition training group in the basic module except that the current training is performed in the presence of background noise. The signal-to-noise ratio varies according to the response from the subject. If the subject responds correctly, the signal-to-noise ratio is reduced by 2 dB. In the other words, the signal-to-noise ratio is increased by 2 dB. Each session includes 25 trials and there are four choices in each trial.

Group 6   Adaptive Everyday Sentence Recognition in Noise Training

This training group is similar to sentence recognition training group in the default basic module except that it is performed in the presence of background noise. The signal-to-noise ratio varies according to the response from the subject. If the subject responds correctly, the signal-to-noise ratio is reduced by 2 dB. Each session includes 25 trials and there are four choices in each trial.

4.4 Melodic Contour Identification Training Module

While a cochlear implant provides many patients with excellent speech understanding in quiet, music perception and appreciation remains a challenge for most cochlear implant users. Recent studies have shown that a closed-set melodic contour identification (MCI) task could be used to quantify cochlear implant users' ability to recognize musical melodies. This advanced module provides MIDI-based Melodic Contour Identification Training for CI patients to aid them in improving their recognition of melodies, thereby improving their music appreciation. For the MCI task, test stimuli were melodic contours composed of 5 notes of equal duration whose frequencies corresponded to musical intervals. The interval between successive notes in each contour was varied between 1 and 5 semitones; the "root note" of the contours was also varied. Nine distinct musical patterns were generated for each interval and root note condition. This is a screen shot of the display window.
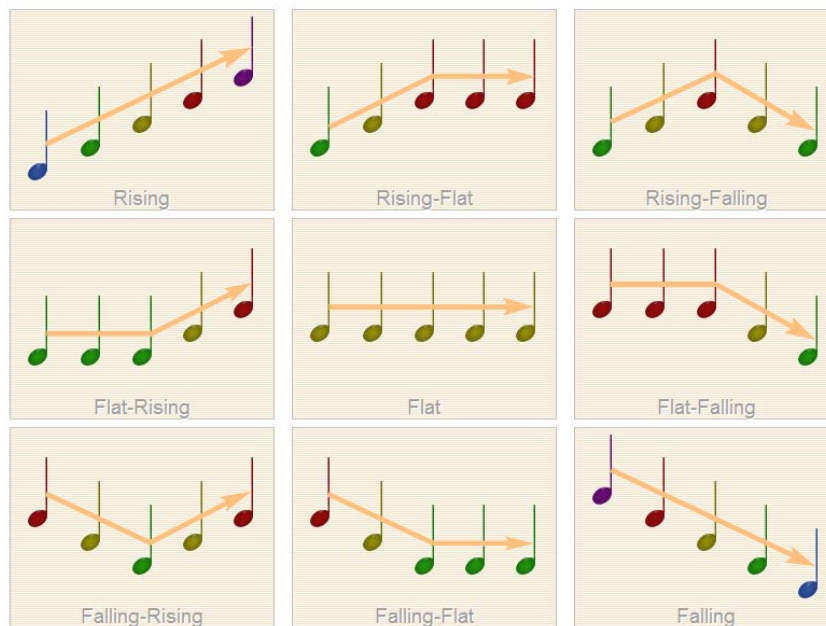
There are four training levels in each training group. The difficulty of each training level is determined by the semitone difference between successive notes, ranging from 5-6 semitones in level 1 to 1 semitone in level 4. Acoustic and visual feedback will be provided with incorrect response during the training.

There are seven different training groups in this module. The training and testing tasks are exactly the same in these groups except that different instruments are used in these groups. The following shows the acoustic wavefrom from different instrument for the same contour pattern.

Instruments	Acoustic Waveform
Tone	
Piano	
Clarinet	
Glockenspiel	
Organ	
Trumpet	
Violin	
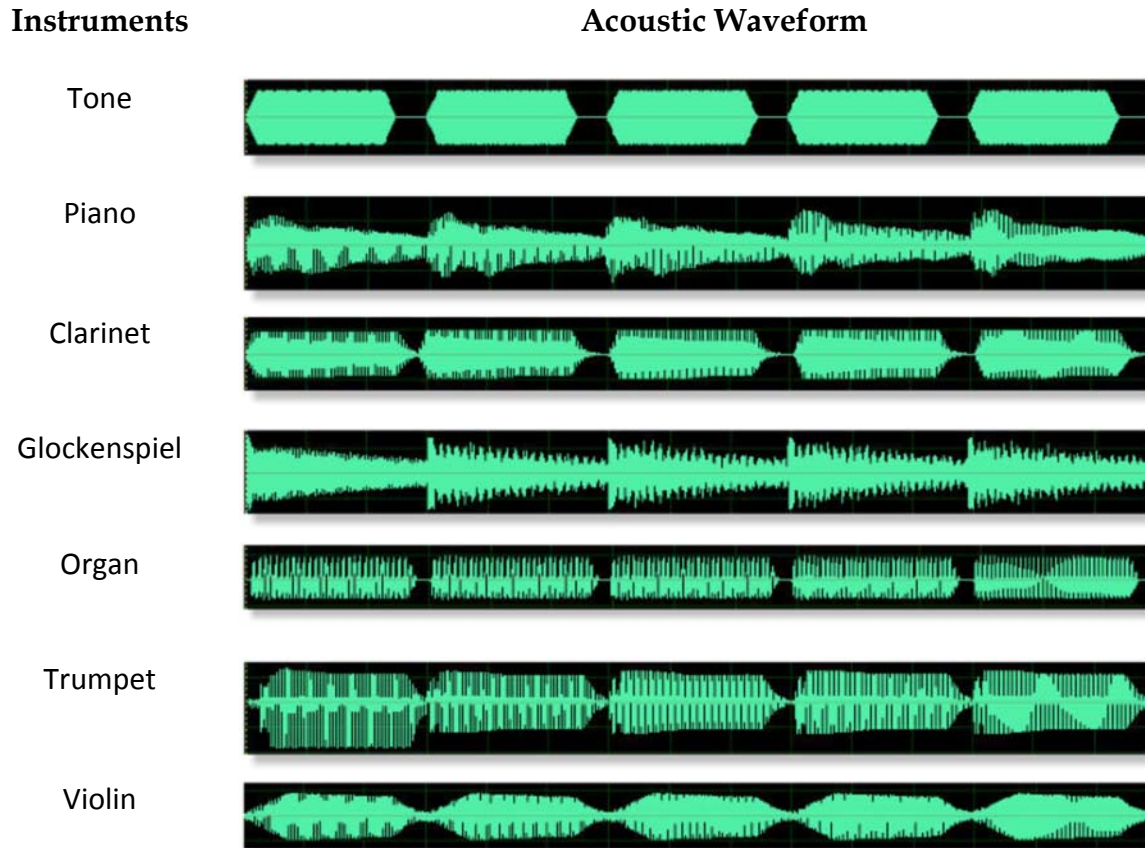
4.5 Advanced Music Training Module

This is an advanced music module which is targeted at various aspects of music appreciation, including basic note discrimination, melodic contour identification, melodic sequence recognition, chord recognition, polyphonic contour identification etc. Many tasks are very difficult so this module is generally suitable for good-performing users.

Group 1: Music Note Discrimination Training

In this group you gain practice in discriminating between different music notes. The training may help your ability to hear differences in the pitch of sounds, a good starting point in developing your language recognition and music perception skills. By listening carefully to the music notes during training and testing, you are given a better sense of the different pitches provided by your cochlear implant. *Note that this training group is very similar to the pure-tone training group in the basic module.*

How the Training Works: All levels present discrimination tasks. In each task, three sounds (music notes) are played, and their corresponding response buttons highlighted. Two of the sounds are the same music notes, while the other sound has a different pitch. Click on the response button you think has the different pitch. As you move up through the levels of difficulty, the tone comparisons (the semitone differences between music notes) become more closely spaced and therefore more difficult to discriminate between. Please perform one testing before the training to determine which level you should be trained. At level 1, the tone comparisons are widely spaced. By level 5, the tone comparisons are the most narrowly spaced. Some tone comparisons may be very difficult, so don't be disappointed if you cannot discriminate all the tones.

Group 2: Melodic Contour Identification Training

While a cochlear implant provides many patients with excellent speech understanding in quiet, music perception and appreciation remains a challenge for most cochlear implant users. Recent studies have shown that a closed-set melodic contour identification (MCI) task could be used to quantify cochlear implant users' ability to recognize musical melodies. This training group provides MIDI-based Melodic Contour Identification Training for CI patients to aid them in improving their recognition of melodies, thereby improving their music appreciation. For the MCI task, test stimuli were melodic contours composed of 5 notes of equal duration whose frequencies corresponded to musical intervals. The interval between successive notes in each contour was varied between 1 and 5 semitones; the "root note" of the contours was also varied. Nine distinct musical patterns were generated for each interval and root note condition. *Note that this training group is very similar to the Piano Training group in the Melodic Contour Identification Module.*

How the Training Works: Melodic contour identification performance was tested by using nine five-note melodic patterns. The nine patterns represented simple pitch contours (e.g., "Rising," "Flat," "Falling") and changes in pitch contour (e.g., "Flat-Rising," "Falling-Rising," "Rising-Flat," "Falling-Flat," "Rising-Falling," "Flat-Falling").

Group 3: Melodic Sequence Identification

This group uses both Open Set Recognition Training Protocols and Speech Synthesis based on Concatenation for assessing/training the listener's ability to identify melodic sequence. The training group is an advanced version of melodic contour identification. The original melodic contour identification only have nine different patterns while the melodic sequence identification allows much more melodic patterns, which is much more difficult than the original melodic contour identification. The interface for this training group is displayed below.
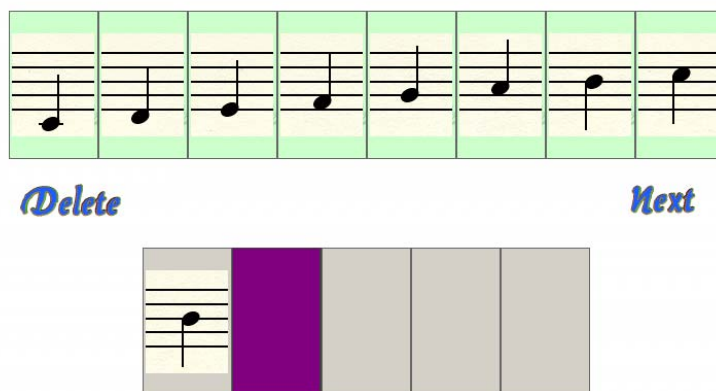
Training Level Summary: There is 25 trials in each run. Here is the training level used in this training group.
- Level 1 (note separation): +3, -3 or 0 semitones difference between the successive notes
- Level 2 (note separation): +2, -2 or 0 semitones difference between the successive notes
- Level 3 (note separation): +1, -1 or 0 semitones difference between the successive notes
- Level 4 (note separation): random semitone difference between the successive notes

## *Group 4: Music Chord Identification*

In this group you gain practice in discriminating between different music chords (combinations of three concurrent notes). The training may help your ability to hear differences in the timbre of chords, a good starting point in further developing your music perception skills. By listening carefully to the music chords during training and testing, you are given a better sense of the combined notes provided by your cochlear implant. Depending on the level of difficulty, the interface for this group is different.

Training Level Summary: There is 25 trials in each run. Here are the three training levels, including

- Level 1 (Discrimination): To detect the difference between any Chords (left panel below)

- Level 2 (Identification): To identify whether the Chord is Major or Minor (right panel above).
- Level 3 (Identification): To identify which chord is playing from the six choices (left panel below).
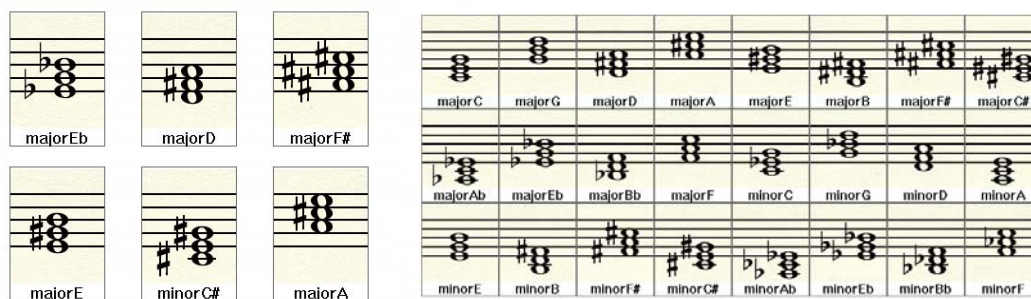
In the preview mode, you are allowed to preview all the chords used in the program (right panel above).

Group 5: Music Contour Segregation

This training group help cochlear implant users segregate competing voices and/or musical instruments. Polyphonic music often involves multiple instruments that interleave and overlap in time, and listeners may use temporal offsets between instruments to track different melodic components. When played simultaneously by multiple sound sources, it is more difficult to track the melodic components. In the present study, the masker and target were presented simultaneously; the onset, duration, and offset for each note of the target and masker were the same. The response interface is same as melodic contour identification.

Training Level Summary: There is 25 trials in each run. Here are the five training levels, including
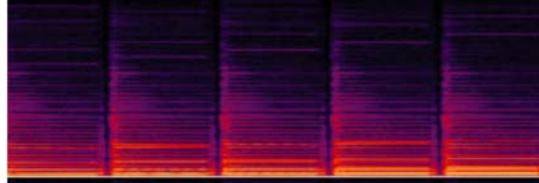
- A4 Masker: Flat Contour with A4 Piano as Masker
- A5 Masker: Flat Contour with A5 Piano as Masker
- A6 Masker: Flat Contour with A6 Piano as Masker
- A7 Masker: Flat Contour with A7 Piano as Masker
- No Masker: No Masker, Same as Melodic Contour Identification

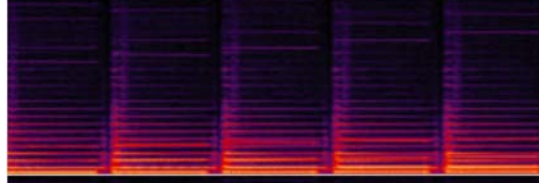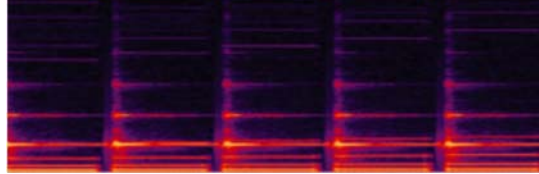The following shows the spectrogram of a rising contour with different maskers.

No Masker
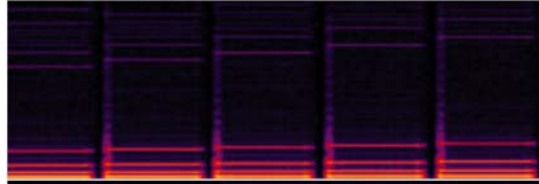
A4 Masker

A5 Masker

A6 Masker

Group 6: Music Instrument Identification

This training group help cochlear implant users improve the identification of different music instruments. The first training level is to identify the instrument from six different instruments. A five-note sequence will be played. The subjects determine the instrument based on the sequence played. The response interface is shown as follows. Training level 2 to 4 is to recognize the sequence of instruments with single note. It is much difficult than the level 1. The response interface for these level is shown as follows:

Training Level Summary: There is 25 trials in each run. Here are the four training levels, including
- Instrument identification (from 6 different instruments)
- 2 Tokens: The sequence of 2 instruments
- 3 Tokens: The sequence of 3 instruments
- 5 Tokens: The sequence of 5 instruments

Group 7: Familiar Melody Identification

This training group help cochlear implant users improve the identification of familiar melodies either with rhythmic cues or without rhythmic cues. Familiar melody identification was also measured for 12 familiar melodies used by Kong et al. (2004, 2005), with and without rhythm cues. Three-harmonic complexes were generated for each note, using the same methods as for melodic contours. The F0 range covered by all melodies was 415 to 1047 Hz. The response interface is shown as follows:

Yankee-Doodle	Twinkle-Twinkle Little-Star	Star-Spangled Banner
Old-MacDonald had-a-Farm	This-Old-Man	She'll-be-Comin' Round-the-Mountain
Mary-had-a Little-Lamb	Lullaby-and-Goodnite	London-Bridge-is Falling-Down
Happy-Birthday to-You	Take-me-out-to the-Ballgame	Auld-Lang-Syne

Training Level Summary: There is 24 trials in each run. Here are the two training levels, one training level contains 12 familiar melody recognition training with rhythmic cues and the other training level contains 12 familiar melody recognition training without rhythmic cues, which is significantly more difficult due to the removal of rhythmic cues.

4.6 Openset Training Module

This advanced module provides several advanced training protocols for different listening situations. It differs from closed set phoneme recognition as there are no explicit choices for each trial. The chance level is close to zero. There are six training groups in this module which target at different listening conditions.

Group 1: Open Set Word Recognition Training

This group uses Open Set Recognition Training Protocols. While this training group uses the same training materials (monosyllabic words) used in the closed set phoneme recognition training, there are no explicit choices in this group. The user must select letters on the screen to identify the words. There are three training levels including word recognition in quiet, in 10 dB SNR and in 0 dB SNR.

A	B	C	D	E	F	G	H	I	J
K	L	M	N	O	P	Q	R	S	T
U	V	W	X	Y	Z	-	'	,	.

Delete   *Next*

main

Group 2: Open Set Sentence Recognition Training

This group uses Open Set Recognition Training Protocols. It is similar to the open set word recognition training; the user must type whole sentences or click the letter in the screen to select the whole sentence. The program calculates the percentage of words correctly identified. There are three training levels in this group, including quiet, 10 dB SNR, and 0 dB SNR. The interface is the same as that used for the word group.

A	B	C	D	E	F	G	H	I	J
K	L	M	N	O	P	Q	R	S	T
U	V	W	X	Y	Z	-	'	,	.

Delete   *Next*

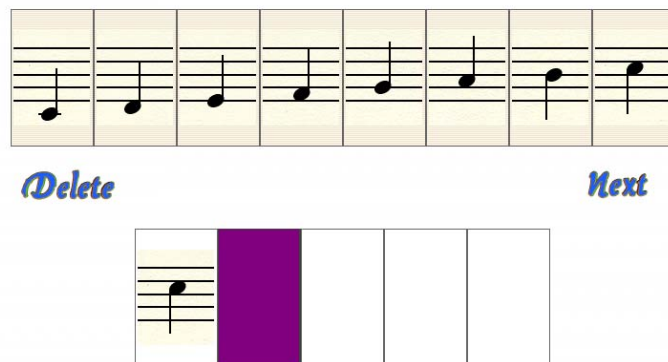it will be done before the boy can see it

Group 3: Digit Recognition Training

This group uses both Open Set Recognition Training Protocols and Speech Synthesis based on Concatenation for assessing/training the listener's digit span, or their ability to recognize the number of digits. The number of digits per string ranges from 3 to 7 (3 digits, 5 digits, and 7 digits). The interface for this training group is displayed below.
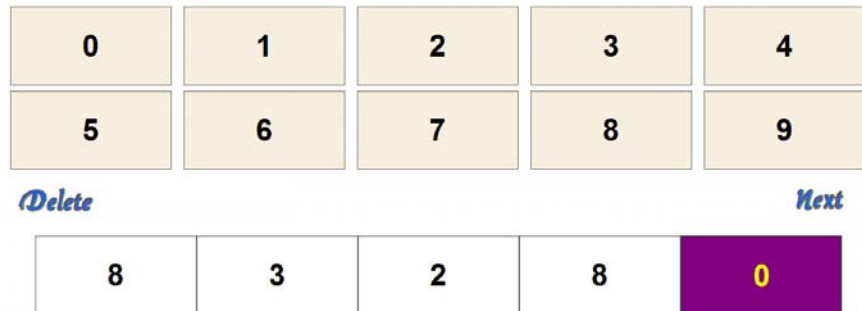
Group 4: Melody Notes Sequence Recognition Training

This group uses both Open Set Recognition Training Protocols and Speech Synthesis based on Concatenation. This training group provides PIANO-based Melodic Sequence Recognition Training for CI patients to improve recognition of musical melodies, thereby improving their music appreciation. This is an open set recognition task. The sequence is random. Test stimuli were melodic sequences composed of 2, 3, 5, or 7 notes of equal duration whose frequencies corresponded to musical intervals. The notes range from C4 to C5. The interface for this group is shown below. *Note that this training group is same as the Melodic Sequence ID training group in the advanced music module.*

Group 5: Instrument Sequence Recognition Training

This training group provides Instrument Sequence Recognition Training for CI patients to improve to help recipients improve their appreciation of music. This is an open set recognition task. The sequence is random. Test stimuli were melodic sequences composed of 2, 3, 5, or 7 notes of equal duration whose frequencies corresponded to musical intervals. This group uses both Open Set Recognition Training Protocols and Speech Synthesis based on Concatenation. The main

interface for this group is shown below. *Note that this training group is same as the Music Instrument Identification group in the advanced music module.*

| piano | violin | trumpet | clarinet |

Delete   *Next*

Group 6: Concatenated Sentence Recognition Training

The Concatenated Speech Training Protocols utilize sentences that include five words in the following order: noun, verb, number, adjective, and noun. Each category includes 10 words providing a total of 100,000 random sentences. The user selects the words from the screen (10x5) to produce the sentence. The program determines the number of correct words and computes percentage points. Again, there are three training levels in this training group, including quiet, 10 dB, and 0 dB. Here shows the interface for this training group.

Peter	owns	ten	old	jackets
Bill	shipped	two	red	boxes
John	sees	seven	good	roses
Gary	bought	three	new	birds
Freddie	won	six	green	windows
Joni	gets	fifteen	lovely	masks
Rachel	sold	eight	pretty	shirts
Dana	borrows	thirteen	big	dogs
Michelle	chose	twelve	yellow	gifts
Cathy	made	eleven	funny	balls

*Delete*   *Next*

Group 7: Recognition Threshold Training for Words, Sentences, Digits, and Concatenated Sentences

This group uses several Advanced Training Protocols including Open Set Recognition Training Protocols, Speech Synthesis based on Concatenation, and Trial-based Adaptive Speech in Noise Training. The tasks in this group are designed to assess/train the listener's ability to recognize words, sentences, or digits in the presence of background noise. The background noise consists of six-talker speech babble. Speech recognition thresholds and the signal-to-noise ratio will be measured. The digit string has 3 digits. The main interface is the same used for the above groups.

4.7 Auditory Resolution Training Module

The Auditory Resolution Training Module provides you with the opportunity to listen to and distinguish sounds differed in one specific domain, such as spectral, temporal, and amplitude etc. This training group is aimed at improving the ability to discriminate the subtle acoustic difference among these sound, thus improving speech understanding.
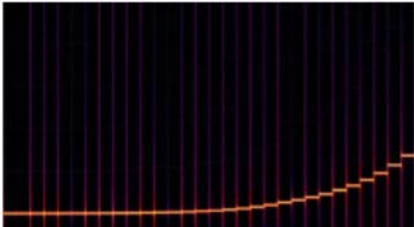
Click on the different sound 👆

Sound 1 is Different	Sound 2 is Different	Sound 3 is Different
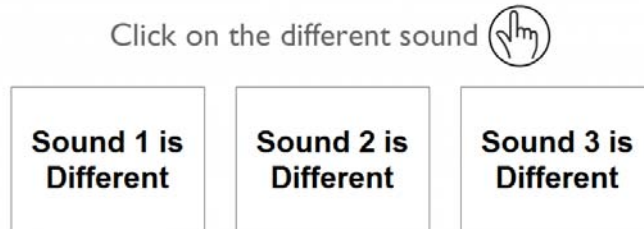
This training module covers frequency discrimination, modulation detection, temporal gap detection, amplitude discrimination, forward masking, and pure tone detection.

Group 1: Frequency Discrimination Training

The Frequency Discrimination Group provides you with the opportunity to listen to and distinguish sounds differed in the frequency domain. This training group is aimed at improving the ability to discriminate the subtle frequency difference among these sound, thus improving speech understanding. The first three tasks are targeted at music notes while the last one is targeted at 1kHz pure tone. 3AFC (3 alternative forced choice) will be used for all auditory resolution training. In this protocol, the computer will play three sounds, the listener has to identify which sound is different from the other two. The difference (in this case, frequency) between the reference and target signal will be adaptively adjusted according to the response of the listener. Basically, the difference will be gradually reduced when the response is correct and increased when the response is not correct.

List of stimuli with different frequencies

	Stimulus List	Spectrogram

Music Notes

A3	A#3	B3	C3	C#3	D3	D#3	E3	F3	F#3	G3	G#3
A4	A#4	B4	C4	C#4	D4	D#4	E4	F4	F#4	G4	G#4
A5	A#5	B5	C5	C#5	D5	D#5	E5	F5	F#5	G5	G#5
A6	A#6	B6	C6	C#6	D6	D#6	E6	F6	F#6	G6	G#6
A7	A#7	B7	C7	C#7	D7	D#7	E7	F7	F#7	G7	G#7

Pure Tones

| 1000.0 Hz	1001.0 Hz	1001.5 Hz	1002.3 Hz	1003.4 Hz	1005.1 Hz	1007.6 Hz	1011.4 Hz
1017.1 Hz	1025.6 Hz	1038.4 Hz	1050.0 Hz	1065.0 Hz	1084.5 Hz	1109.8 Hz	1142.7 Hz
1185.6 Hz	1241.2 Hz	1313.6 Hz	1407.7 Hz	1530.0 Hz	1636.0 Hz	1763.2 Hz	1915.8 Hz
2099.0 Hz	2318.7 Hz	2582.5 Hz	2899.0 Hz	3278.8 Hz	3734.6 Hz		

Group 2: Modulation Detection Training

The Modulation Detection Group provides you with the opportunity to listen to and distinguish sounds differed in the temporal modulation. This training group is aimed at improving the ability to discriminate the subtle temporal fluctuation difference among these sound, thus improving speech understanding. All five tasks are similar except that the modulation frequency is different (10, 20, 50, 100, and 200 Hz). Stimuli for all signals with different modulation depth. No=no modulation; -40=1% of modulation depth; 0=100% of modulation depth.
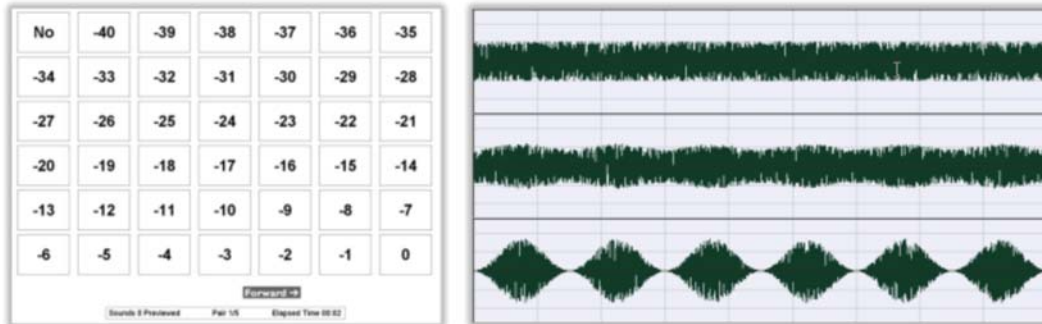
Group 3: Modulation Frequency Discrimination

The Modulation Frequency Discrimination Group provides you with the opportunity to listen to and distinguish sounds differed in the temporal modulation. This training group is aimed at improving the ability to discriminate the subtle temporal fluctuation difference among these sound, thus improving speech understanding. All five tasks are similar except that the modulation frequency is different (10, 20, 50, 100, and 200 Hz). Stimuli for all signals with different modulation frequency:
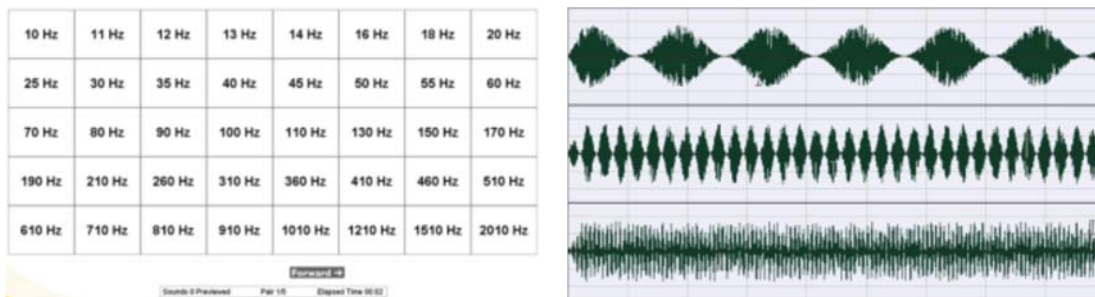
Group 4: Temporal Gap Detection Training

The Temporal Gap Detection Group provides you with the opportunity to listen to and distinguish sounds with gap in between. This training group is aimed at improving the ability to discriminate the subtle temporal gap among the signals, thus improving speech understanding. The gap is located in the middle of two signals. These signals can be the same or different. Three signals are

used, including noise, 1kHz, and 2kHz pure tones. Here is the stimulus list for the temporal gaps as well as the waveform for signals with different temporal gaps.
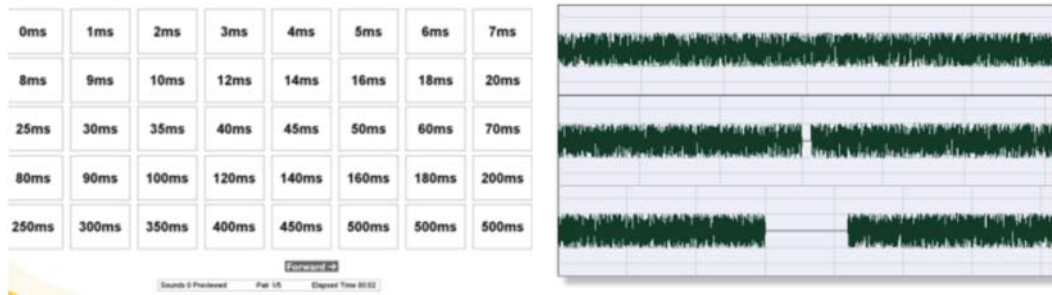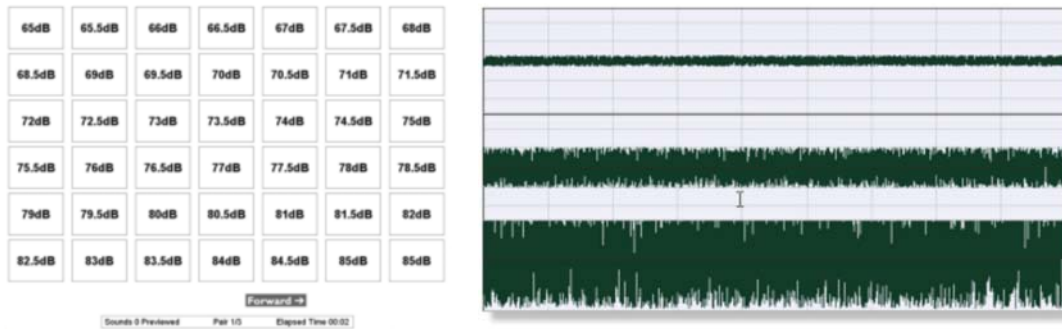

Group 5: Amplitude Discrimination Training

The Amplitude Discrimination Group provides you with the opportunity to listen to and distinguish sounds with different levels. This training group is aimed at improving the ability to discriminate the subtle amplitude difference among the signals, thus improving speech understanding. Three signals are used, including noise, 1kHz, and 2kHz pure tones. Here is the stimulus list of signals with different amplitude level as well as the acoustic waveform of three stimuli with different amplitude levels.

Group 6: Tone Detection with Masker (Forward Masking) Training

The Tone Detection with Masker Group provides you with the opportunity to listen to and distinguish sounds when there is a masking signal. This training group is aimed at improving the ability to detect a sound when there is an interfering signal, thus improving speech understanding. The masker is white noise while the probe signal is a 1kHz tone. The gap between masker and probe varies from 10ms to 100ms. Here is the stimulus level of signals with different probe levels as well as the acoustic waveform of signals with three different level of probe signals.

Group 7: Puretone Threshold Detection Training

The Pure Tone Threshold Group provides you with the opportunity to listen to and detect very weak sounds. This training group is aimed at improving the ability to detect a weak sound, thus improving speech understanding. Five different pure tones are used in this group, including 250, 500, 1000, 2000, and 4000 Hz. Here is the stimulus list of sound with different level as well as the acoustic waveform of pure tone at different amplitude level.
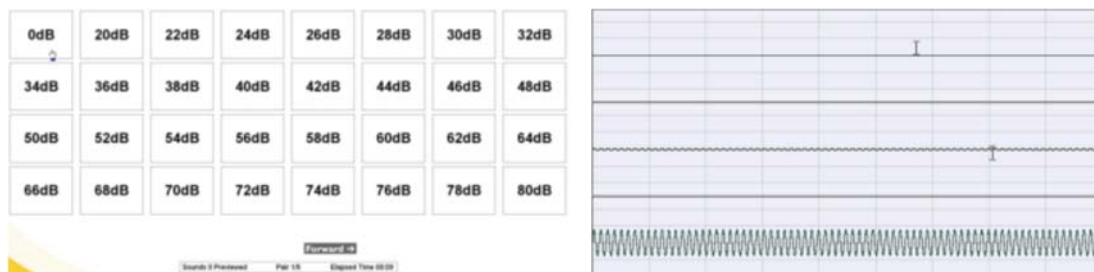

Group 8: Music Rhythm Test and Training

The Music Rhythm Test and Training Group provides you with the opportunity to listen to and distinguish musical rhythms in a melodic sequence. This training group is aimed at improving the ability to listen to the subtle rhythmic changes, thus improving music appreciation. All six tasks are similar except that the change occurs in 2nd or 3rd notes with either flat, rising, or falling note patterns. Here is the stimulus level of signals with different gaps and the corresponding acoustic waveform at three different gaps.
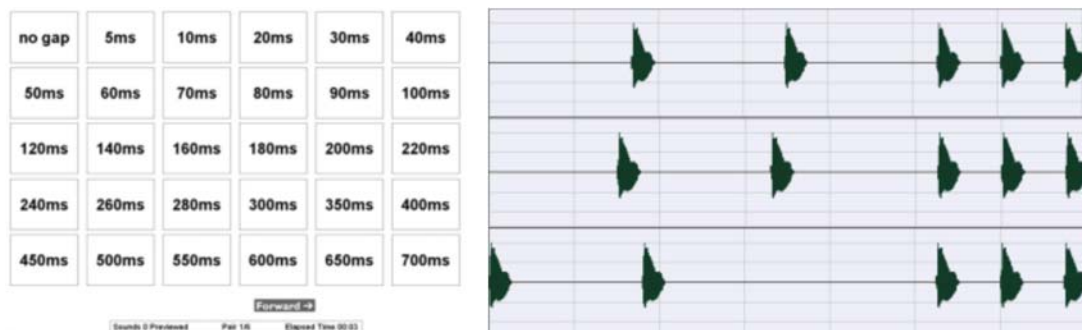
4.8 Functional Hearing Test Module

It is important to use appropriate functional hearing test to assess whether hearing-impaired people benefit from their cochlear implant or hearing aid. Most well-known standardized function hearing tests are openset sentence or word recognition. However, openset recognition tasks are difficult for hearing-impaired people to administer at home alone since these tasks generally require third-party to perform. While Angel Sound is primarily developed for auditory rehabilitation, the CAST technology used in the Angel Sound is essentially a perfect self-administered assessment tool for functional hearing test. One of the powerful features in the Angel Sound is the seamless integration of speech training and testing function. While many self-administered speech recognition tasks have been implemented in the Angel Sound program, most of them are located in the different modules due to the nature of modular implementation. The function hearing test module in the Angel Sound is developed to incorporate most commonly used speech and music recognition tasks into a single module so the user can quickly find the appropriate tasks for assessing their functional hearing status.

Group 1: Auditory Resolution Tests

Objective: The Auditory Resolution Test Group is to determine your ability to distinguish sounds differed in one specific domain, such as spectral, temporal, and amplitudes. The tasks in this group are aimed at assessing the listeners' ability to discriminate the subtle acoustic difference across among these sounds, which is the foundation for complex speech perception. Psychoacoustic procedure is used to determine the minimal just-noticeable-difference in frequency, gap, and modulation depth.

Tasks: This test group has three different discrimination tests, including
- **Frequency discrimination:** The ability to discriminate the difference in spectral domain. The recognition threshold for normal-hearing listener is about 0.5 semitones (due to the limits in the setup, basically the resolution is generally better than 0.5 semitones).

Sound 1 is Different	Sound 2 is Different	Sound 3 is Different
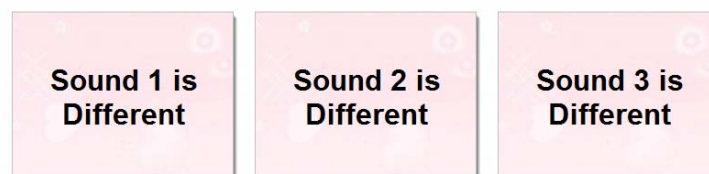
- **Gap detection:** The ability to identify the minimal gap between two noise bursts. The recognition threshold for normal-hearing listener is about 2 ms.
- **Temporal modulation detection:** The ability to detect the minimal temporal modulation. The recognition threshold for normal-hearing listener is about -25 dB.

Group 2: Phoneme Recognition Test

Objective: The Phoneme Recognition Test Group is to determine your ability to distinguish between phonemes which are the building blocks of language. Commonly used vowel and consonant recognition tests are used in this test group. The tasks in this group are aimed at

assessing the ability to discriminate the subtle acoustic difference among different phonemes, which may be the foundation for complex speech perception.

Tasks: This test group has three different identification tests, including

- **Vowel recognition test:** The ability to identify 12 different vowels (left panel below). The expected percent correct should be 100% for normal-hearing listeners.

- **Consonant recognition test:** The ability to identify 20 different consonants (right panel above). The expected percent correct should be 100% for normal-hearing listeners.
- **Voice gender identification:** The ability to identify voice genders of given sounds. The expected percent correct should be 100% for normal-hearing listeners.

Group 3: Music Perception Test

Objective: The Music Perception Test Group is to determine your ability to identify various melodic contours, different music instruments as well as familiar melodies. While a cochlear implant provides many patients with excellent speech understanding in quiet, music perception and appreciation remains a challenge for most cochlear implant users.

Tasks: This test group has three different identification tests, including

- **Music note discrimination test:** The ability to detect minimal difference between two music notes (left panel below). The expected score should be about 0.5 semitones (due to the limits in the setup, basically the resolution is generally better than 0.5 semitones).

- **Melodic contour identification test:** The ability to identify nine different melodic contours. The expected percent correct should be 100% for normal-hearing listeners (right panel above).
- **Musical instrument identification test:** The ability to identify six different instruments. The expected percent correct should be 100% for normal-hearing listeners (left panel below).

- **Familiar melody identification:** The ability to identify 12 familiar melodies without rhythms. The expected percent correct should be 100% for normal-hearing listeners (right panel above).

Group 4: Speech Recognition in Noise Test

Objective: The Speech Recognition in Noise Test Group is to determine your ability to understand speech in the presence of background noise. Recognition threshold, which is defined as the signal-to-noise ratio that produces 50% of speech recognition, will be measured. The lower the recognition threshold, the better you can handle conversation in the daily life where noise is always present.

Tasks: This test group has two different identification tests, including
- **Digits in Noise Test:** The ability to recognize 3 digits in the presence of speech babble. The expected recognition threshold should be about -14 dB for normal-hearing listeners.
- **Keyword in Noise Test:** The ability to understand sentence in the presence of speech babble. The program will play IEEE sentences and randomly pick six keywords from various sentences. The listener has to identify the only keyword that has been mentioned in the sentence. The expected recognition threshold should be about -15 dB for normal-hearing listeners.

Group 5: Auditory Cognition (Working Memory) Test

Objective: Auditory Cognition Test Group is to assess the listeners' ability of remembering auditory objects, such digits or different sound patterns. Recognition threshold, which is defined as the number of auditory objects in which the listeners can correctly remember 50% of time,

will be measured. The higher the recognition threshold, the better you can remember the auditory objects. The better auditory memory may be related to the better auditory perception.

0	1	2	3	4
5	6	7	8	9

Delete   *Next*

4	2	**7**

Tasks: This test group has two different recognition tests, including
  • **Forward digit span test:** The ability to remember digit sequence in a forward fashion. The expected recognition threshold should be about 10 digits for normal-hearing listeners.
  • **Backward digit span test:** The ability to remember digit sequence in a backward fashion. The expected recognition threshold should be about 10 digits for normal-hearing listeners.

Group 6: Openset Word Recognition Test

Objective: Openset recognition test is the ultimate speech recognition test to assess the listeners' speech understanding in real-life conversation. The traditional openset recognition test generally requires third party to perform the test, which make it difficult to self-administer at home. Openset Word Recognition Test Group uses the well-known CNC word list for the test but allow the user to type their response with keyboard or mouse click.

A	B	C	D	E	F	G	H	I	J	K	L	M
N	O	P	Q	R	S	T	U	V	W	X	Y	Z

Delete   *Next*

would

Tasks: This test group has three CNC word lists. Select either list to start the test. After hearing the word, type the word or click the letter in the screen to complete the word. The expected percent correct should be 100% for normal-hearing listeners.

4.9 Learning by Listening Module

It is important to use age-appropriate listening materials for hearing-impaired children who have cochlear implant device or hearing aid device to facilitate their language development. The learning by listening module in the Angel Sound is developed to incorporate scheme-based training protocols for children with cochlear implant device or hearing aid device to discriminate different sounds as well as learn new words.

Group 1: Learning ABC

The Learning ABC Group is to help the children to discriminate and identify all 26 English letters (A-Z) spoken by different speakers under different listening environments, including quiet, phone conversation, music background. The tasks in this group are aimed at improving the listeners' ability to discriminate the acoustic difference across among these letters, which is the foundation for learning new words.

This test group has four different listening environments, including
1. Quiet: The letters are presented in quiet listening conditions.
2. Phone: The letters are presented via traditional phone line with limited bandwidth (300-3200Hz).
3. 10-dB: The letters are presented in the presence of music background with 10 dB SNR.
4. 0-dB: The letters are presented in the presence of music background with 0 dB SNR.

Group 2: Learning Food Name

The Learning Food Name Group is to help the children to discriminate and identify about 100 different food name spoken by different speakers under different listening environments, including quiet, phone conversation, music background. The tasks in this group are aimed at improving the listeners' ability to discriminate the acoustic difference across among these food names, which is important in their daily.

This test group has four different listening environments, including
1. Quiet: The food names are presented in quiet listening conditions.
2. Phone: The names are presented via traditional phone line with limited bandwdith (300-3200Hz).
3. 10-dB: The food names are presented in the presence of music background with 10 dB SNR.
4. 0-dB: The food names are presented in the presence of music background with 0 dB SNR.

Group 3: Learning Animal Name

The Learning Animal Name Group is to help the children to discriminate and identify about 100 different animal name spoken by different speakers under different listening environments, including quiet, phone conversation, and music background. The tasks in this group are aimed at improving the listeners' ability to discriminate the acoustic difference across among these animal names.

This test group has four different listening environments, including
1. Quiet: The animal names are presented in quiet listening conditions.
2. Phone: The names are presented via traditional phone line with limited bandwidth (300-3200Hz).
3. 10-dB: The animal names are presented in the presence of music background with 10 dB SNR.

4. 0-dB: The animal names are presented in the presence of music background with 0 dB SNR.

Group 4: Learning Colors

The Learning Color Group is to help the children to discriminate and identify 12 common colors spoken by different speakers under different listening environments, including quiet, phone conversation, and music background. The tasks in this group are aimed at improving the listeners' ability to discriminate the acoustic difference across among these color names.

This test group has four different listening environments, including
1. Quiet: The color names are presented in quiet listening conditions.
2. Phone: The names are presented via traditional phone line with limited bandwidth (300-3200Hz).
3. 10-dB: The color names are presented in the presence of music background with 10 dB SNR.
4. 0-dB: The color names are presented in the presence of music background with 0 dB SNR.

Group 5: Learning Numbers

The Learning Number Group is to help the children to discriminate and identify 20 common numbers (1-20) spoken by different speakers under different listening environments, including quiet, phone conversation, music background. The tasks in this group are aimed at improving the listeners' ability to discriminate the acoustic difference across among these numbers.

This test group has four different listening environments, including
1. Quiet: The numbers are presented in quiet listening conditions.
2. Phone: The numbers are presented via phone line with limited bandwidth (300-3200Hz).
3. 10-dB: The numbers are presented in the presence of music background with 10 dB SNR.
4. 0-dB: The numbers are presented in the presence of music background with 0 dB SNR.

Group 6: Phonetic Contrast

The Phonetic Contrast Training Group is to help the children to discriminate and identify words with minimal phonetic contrast spoken by different speakers under different listening environments, including quiet, phone conversation, and music background. The tasks in this

group are aimed at improving the listeners' ability to discriminate the acoustic difference across among different words with minimal phonetic contrast.

This test group has four different listening environments, including
1. Quiet: The words are presented in quiet listening conditions.
2. Phone: The words are presented via phone line with limited bandwidth (300-3200Hz).
3. 10-dB: The words are presented in the presence of music background with 10 dB SNR.
4. 0-dB: The words are presented in the presence of music background with 0 dB SNR.