DEVELOPMENT OF A MUSIC BASED MOBILE AUDITORY TRAINING GAME

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INTRODUCTION

Auditory training has been demonstrated to produce measurable speech-in-noise benefits [1]. The convenience and relatively low cost of computer assisted training programs have made it easier for clinicians to employ auditory training as a component of a comprehensive auditory rehabilitation plan. To encourage compliance, training programs that are interesting and entertaining could reduce dropout rates and improve the effectiveness of the training [2].

A patent-pending computer-assisted auditory training program was developed at our laboratory. This program uses a game format to challenge the trainee's auditory, attention, memory, and problem solving skills. The program was implemented as a mobile application for an iPad and an iPhone. Unlike the typical auditory training programs that use speech as the source material, the current program uses melodies played with various musical instruments as a medium. While music is used, the primary goal of the program is not to train the listeners to become practicing musicians as is typically done with ear-training programs. Rather, the program was developed to support auditory rehabilitation through the use of music so people of most, if not all language backgrounds, may participate.

WHY USE MUSIC AS A TOOL?

- Music is more universal and language independent than speech. More people with different language backgrounds can use the program as is. This increases the number of people who can use the program and eliminates any post-development costs associated with modifying the program into other languages.
- Simple musical sounds are free from semantic or emotional associations that may be present in speech signals. Thus, they may allow listeners to focus their attention on the details of the training stimuli.
- Musical melodies can be synthesized with relative ease. This makes it an ideal stimulus where one has precise control of the parameters meeting the listener's skill level.

MUSIC TRAINING EFFECTS

Traditional music training can induce functional and structural changes in the auditory system. Musical training can also improve non-musical auditory skills.

- Enhanced subcortical encoding of speech in quiet and in noise. This includes faster neural response times, higher neural response consistency, more robust encoding of speech harmonics, and greater neural precision [3].
- Enhanced ability to hear speech in challenging environments such as noisy backgrounds [4].
- More differentiated cortical evoked potentials to small acoustic dissimilarities [5].
- Improved ability to perceive and produce non-native speech [6] [7].
- Improved auditory attentional control [8].
- Better auditory working memory [9].
- Enhanced executive functioning [10].

MUSIC TRAINING EFFECTS

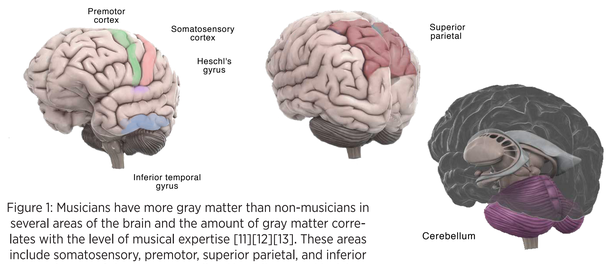
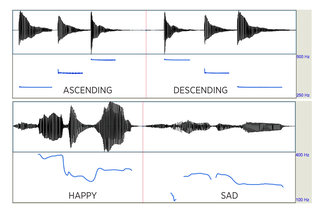


Figure 1: Musicians have more gray matter than non-musicians in several areas of the brain and the amount of gray matter correlates with the level of musical expertise [11][12][13]. These areas include somatosensory, premotor, superior parietal, and inferior temporal areas of the cortex as well as Heschl's gyrus. Musicians also have larger cerebellar volume.

MUSIC/SPEECH SIMILARITIES

Figure 2: In music, pitch communicates melodies and tone centers (example right upper: ascending and descending three note melodies with blue lines showing the pitch trajectories). In speech, pitch patterns communicate prosodic information such as speaker's emotion and intention (example right lower: utterance "please say the word" in happy and sad emotions with blue lines showing the pitch trajectories). Underlying perceptual attribute of pitch is periodicity, which is encoded through similar patterns of action potential timing in auditory neurons at the subcortical level for both music and speech [14].



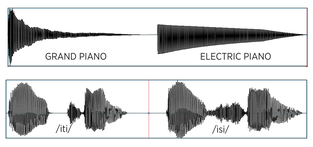


Figure 3: In music, timing indicates rhythm. Each musical instrument has its own characteristic temporal envelope (example left upper: temporal envelopes of grand- and electric pianos playing the same note). In speech, timing conveys prosodic information. It also indicates phonetic cues such as release bursts of stop consonants (example left lower: temporal envelopes of /iti/ and /isi/) and is used contrastively in some languages. Musically trained individuals have earlier and larger brainstem responses than nonmusicians for music and speech [15][16].

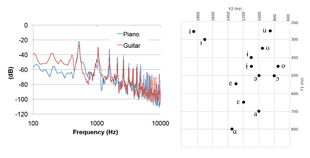


Figure 4: Each musical instrument and playing style has a unique timbre (example right: piano and guitar playing the same note showing unique spectra). In speech, spectrum is used to define speech formants, which are important for distinguishing phonemes (example right: formant chart displaying spectral peak frequency characteristic for different vowels). The harmonics of the stimulus are represented more robustly in individuals trained in music than nonmusicians for speech [17] and for music [18].

Pitch, timing, and timbre have distinct subcortical representations, which can be selectively enhanced with training [15]. The quality of subcortical encoding is greater in musically trained listeners than nonmusicians [19], and has been correlated with speech understanding-in-noise capability [20].

MUSIC PUZZLE (MUZZLE)

Muzzle is a music puzzle game that is solved by listening to melodies represented by a square matrix of N x N (N = 3 or 4) tiles. Each tile is associated with a unique melody that shares at least one feature with other melodies used in the game. Players listen to all the musical notes in the matrix, and try to fill the missing pieces when prompted.

The musical training materials are selected to provide targeted experience in processing of pitch, timing, and timbre. They share the same processing mechanisms in the subcortical structures by both music and speech. (Disclaimer: *It is not known if the effect of playing with this game is similar to the effect of music training or language specific auditory training*).

The musical features that are varied in the game include: absolute pitches of notes in the melodies, the number of identical intervals between melodies, sequential order of notes in the melodies, the temporal characteristics of notes, the number of notes in the melodies, and the timbre of the notes.

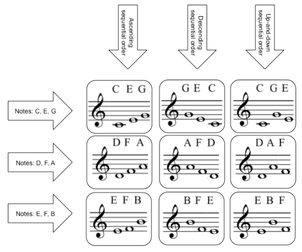
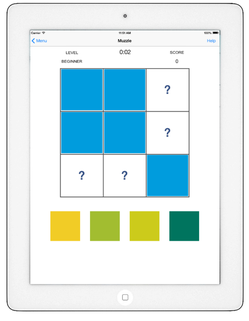


Figure 5: An example arrangement of melodies in a 3 x 3 game matrix. Melodies at each row have identical absolute note pitch values, while the melodies at each column have an identical sequential order of notes (ascending/descending/up-and-down).

- The difficulty of each individual game is defined by the (1) perceptual similarity within each feature, (2) size of the matrix, (3) number of squares removed from the matrix, and (4) number of notes used in the melodies.
- The perceptual similarity/difference between melodies is defined by: the pitch distance, the number of identical intervals, the temporal duration of notes, and the amount of filtering.



HOW TO PLAY MUZZLE

(1) Discovery stage

- Player listens to all the melodies and discovers relationships between them.
- All sounds can be listened to unlimited times.
- All tiles are visually identical so only auditory cues can be used.

(2) Recognition stage

- When player is confident that she/he has discovered the pattern, a number of tiles (4 or more) are removed from the matrix.
- The removed tiles are positioned below the game matrix.
- Listener is to listen to the removed tiles, and to drag-and-drop the tiles to their correct locations.

INDIVIDUALIZATION

- The musical features used in the game are determined on a trial-by-trial basis. The set of possible features can either include all features, or may be customized based on the individual needs.
- The difficulty of the game is adjusted iteratively in real-time based on player's performance. The player is rewarded with "points" based on his/her performance (level/accuracy/speed/time to complete) for motivation.
- The player can advance in levels (beginner/intermediate/advanced/expert) when he/she improves performance.
  - Game-like aspect of the training was selected to promote interest, to motivate, and to increase attention towards training.
  - Game aspect may promote repetition by challenging the trainee to improve their performance.

TECHNICAL SPECIFICATIONS

- Four different instruments: grand piano, electric piano, classical guitar, and electric guitar.
- The notes used in melodies are selected from a five octave range from $A\#_2$ (110 Hz) to C_7 (2093 Hz). The signal is sampled at 44.1 kHz allowing upper harmonics of each note to extend above 18 kHz.
- The game was implemented for iOS 7 operating system used in iPad, iPhone, and iPod Touch devices.

REFERENCES

Scan for a complete list of references.

Scan for a copy of the poster.

If you are interested to help evaluate the efficacy of this app (or just want to have the app), please leave your contact information with one of the authors.

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