The Effects of Training on Melody Recognition and Appraisal by Adult Cochlear Implant Recipients

Kate Gfeller, Shelley Witt, Julie Stordahl, Maureen Mehr, and George Woodworth
The University of Iowa

The purpose of this study was to examine the effect of structured training on melody recognition and appraisal by adult cochlear implant recipients. Twenty-four implant users (Nucleus CI24M) were randomly assigned to a control or training group. Following pretesting the control group experienced 3 months of incidental exposure to music in their normal routine, and the training group completed 12 weeks of training at home. The control group showed no significant changes pre- to posttest on the dependent variables. The training group showed significant gain from pre- to posttest for recognition ($p < .0001$) and appraisal ($p < .0001$) of complex melodies.

The cochlear implant was initially designed to assist people with verbal communication, by transmitting features of the acoustical signal believed most salient to speech perception. Although implant recipients show considerable variability on speech perception measures, many individuals achieve impressive accuracy in open-set speech recognition following experience with the implant in everyday communicative situations. Longitudinal studies reveal that the greatest improvements in speech perception occur by 3 months post-implantation (some achieving dramatic improvement even within 1 month), with much of the eventual im-

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Kate Gfeller, School of Music, Department of Speech Pathology and Audiology, Iowa Cochlear Implant Research Center; Shelley Witt, Department of Otolaryngology; Julie Stordahl, School of Music; Maureen Mehr, Department of Otolaryngology, University of Iowa Health Care; George Woodworth, Department of Statistics and Actuarial Science.

Correspondence concerning this article should be addressed to Kate Gfeller, Department of Otolaryngology, University of Iowa Hospitals and Clinics, 21201 PFP, 200 Hawkins Drive, Iowa City, Iowa 52242. Electronic mail may be sent via Internet to kay-gfeller@uiowa.edu.

provement achieved by 9-months post implantation. Less dramatic though steady improvement may occur as long as 4 years post-implantation (Tyler, Parkinson, Woodworth, Lowder, & Gantz, 1997; Tyler & Summerfield, 1996).

In contrast, anecdotal reports, questionnaires, and experimental data indicate that music listening is much less satisfactory post-implantation than prior to deafness (Gfeller, 1998; Gfeller, Christ, et al., 2000; Gfeller, Knutson, Woodworth, Witt, & DeBus, 1998; Gfeller, Woodworth, Witt, Robin, & Knutson, 1997). Although implant recipients perceive basic rhythm patterns similarly to normal hearing adults (Gfeller et al., 1997), perception for pitch, pitch sequences, and melody recognition is significantly poorer than that of normal hearing adults (e.g., Dorman, Basham, McCandless, & Dove, 1991; Dorman et al., 1990; Fujita & Ito, 1999; Gfeller et al., 1998; Gfeller et al., 1997; Gfeller & Lansing, 1991, 1992; Pijl, 1997; Pijl & Schwartz, 1995; Schultz & Kerber, 1994). This is unfortunate given the pervasiveness of music in everyday life (e.g., concerts, TV, movies, radio, background music in places of business, religious and social events, as a marker of holidays, etc.). According to Stainsby, McDermott, McKay, and Clark (1997), music appreciation is the second most commonly expressed desire, after speech perception, among implant recipients.

Unlike speech perception, greater perceptual accuracy and enjoyment of music is not strongly correlated with length of implant use (Gfeller, Christ, et al., 2000; Gfeller et al., in press). Mere experience with the implant does not seem to result in notable gains in music listening. The device is designed to transmit speech sounds and not important features of music (i.e., pitch resolution), explaining some of the problems with music perception and enjoyment.

In addition, there are important differences between speech and music in form and function that may contribute to limited benefit from incidental or mere exposure to music, as compared with speech. Music listening differs from verbal discourse in opportunities for visual cues, confirmation of perceptual accuracy, or methods for repair. For example, in a conversation, the listener can speechread, rely on body language and facial gestures, ask for clarification, use contextual cues regarding the topic, or compare the acoustical signal to written forms such as closed captioning. The listener has ample opportunity to associate particular acoustical events with specific words. In contrast, many aspects of music production (e.g., whether the melody moves higher or lower, changes in harmony) are not readily visible, even while watching a musical performer, and many implant recipients cannot read musical notation to confirm the accuracy of their perception. When listening to background music on the radio or stereo, visual cues regarding the source of the sound are completely unavailable. In addition, questionnaire data (Gfeller, Christ, et al., 2000) indicate that some implant recipients are so dismayed by the initial quality of music post-hookup that they actively avoid music listening, an activity typically associated with pleasure and cultural enrichment. Consequently, they miss out on possible improvement that might result with more listening practice.

On the other hand, there are significant correlations between self-report of musical enjoyment and the amount of time *devoted* to music listening post-implantation (Gfeller, Christ, et al., 2000; Gfeller et al., 1998). Many implant recipients indicate that music sounded quite distorted or unpleasant initially and that melodies sounded like random pitches. However, some implant recipients report they have developed appreciation and improved perceptual accuracy for some types of music following focused and repeated practice listening to music over many months or years (Gfeller, 1998).

Is it possible for a larger proportion of implant recipients to experience greater satisfaction in music listening with appropriate listening experience? Systematic research is required to determine which factors contribute to improved music listening, and whether those factors can be successfully integrated into a structured aural rehabilitation program.

Because the word *music* encompasses such a large universe of sounds (e.g., solos to large orchestras, different musical styles, vocal, instrumental, live or presented over stereo, etc.), it is difficult to account for all the variables that influence music listening for implant recipients. However, questionnaire data from a sample of 65 experienced adult implant users indicate several factors that implant recipients themselves have considered especially influential (Gfeller, Christ, et al., 2000). Given the well-documented problems associated with background noise, it is no surprise that 83% reported music listening to be enhanced by a quiet listening environment without competing noise or echo. Although implant recipients cannot always control their listening environment, they can make more judicious choices in listening environments when trying to optimize music listening if made aware of this factor.

Other key factors affecting listening satisfaction are associated with characteristics of the music itself. For example, 75% report that they are better able to understand music that has a "simple structure," although it is not clear from the questionnaire responses what actually constitutes "simple structure." Seventy-five percent also report that music familiar prior to hearing loss is easier to understand and enjoy. Presumably, memory for the music provides contextual information that can help the implant user to compensate for those features that are not effectively transmitted peripherally. It is not clear, however, whether implant recipients are able to learn music that is unfamiliar prior to hearing loss. Sixty-six percent indicate that clear rhythm patterns or steady beat assist in understanding and enjoying music. This seems plausible, given that implant recipients have similar perceptual accuracy as normal hearing listeners for rhythmic aspects of music (Gfeller et al., 1997). However, it is not yet known to what extent rhythmic cues contribute to perceptual accuracy or enjoyment.

The purpose of this study was to test the effects of a structured music training protocol for specific types of music listening tasks that incorporate factors of familiarity, structural simplicity, and rhythmicity: recognition of simple melodies, recognition of complex songs, and appraisal (liking) of complex songs.

Simple Melody Recognition

For the purposes of this study, the category of "simple melody" refers to (a) particular patterns of pitches which become known as a cohesive melody unit and are identified with a song title resulting from cultural convention (e.g., "Happy Birthday," "Yankee Doodle," etc.); (b) are produced by a solo musical instrument (thus having only one timbre, or tone quality); and (c) have no lyrics (i.e., linguistic cues) accompanying the pitch patterns. The listener must identify the melody from the relationship among the melody's pitches and rhythmic durations.

Melody recognition is a skill common to most novice listeners (no formal music training) who have normal hearing (Smith, Nelson, Grohskopf, & Appelton, 1994). Normal hearing adults use several structural features when trying to recognize a familiar song: the overall contour (overall pitch movement higher and lower) of the melody, the exact pitch changes (interval) from one note to the next (e.g., C4 to E4), and the rhythmic pattern in the melody (Andrews & Dowling, 1991; Dowling & Bartlett, 1981). Overall melodic contour is especially important when listeners are first learning new melodies, whereas exact pitch intervals are of greater importance in recognition of familiar melodies (Dowling & Bartlett, 1981). Rhythmic features also contribute to melody recognition (Monahan & Carterette, 1985; Palmer & Krumhansl, 1987) and enhance recall and recognition (Krumhansl, 1991). However, some normal hearing individuals may attend to one dimension, such as melody or rhythm, at the expense of the other (Monahan & Carterette, 1985).

Normal hearing adults recognize transformations as well as basic forms (exemplars) of familiar melodies. The sequential melody line can be accompanied by simultaneously presented pitches (i.e., harmony, described by Bregman, 1990, as vertical complexity) or the melody line itself can be modified (e.g., theme and variations, musical ornaments such as trills). However, if the melody is altered too dramatically, it is no longer recognizable as the exemplar melody. Research by Trehub, Morrongiello, and Thorpe (1985) indicates that some melodies are more difficult to recognize than are others if the melody has been degraded in some fashion.

While rhythmic information is effectively transmitted through implants, they are not optimal for pitch resolution (Fearn & Wolfe, 1998; McDermott & McKay, 1997; Pijl, 1997); many implant recipients do not have a normal frequency-to-pitch relationship. Thus the relations among notes in a melody (both contour and exact interval changes) are likely to be degraded through the implant, making melody recognition a difficult task for many implant recipients (Gfeller, 1998; Pijl & Schwartz, 1995; Schultz & Kerber, 1994). Research by Schultz and Kerber (1994) and Fujita and Ito (1999) indicate greater recognition for those melodies that have a recognizable rhythmic pattern. Fujita and Ito (1999) report that "most" of a sample of eight Nucleus implant recipients performed below chance after rhythmic patterns or verbal cues (i.e., lyrics) were eliminated. Although some implant recipients have reported that they are able to improve pitch perception with listening practice (Gfeller, 1998), there is as of yet no empirical data to indicate that practice will result in improved accuracy on pitch-based tasks by implant recipients.

Complex Song Recognition

For the purposes of this study, the category of "complex song" refers to (a) cohesive units of melody, harmony, rhythm, timbre, and sometimes sung lyrics that are identified with a song title as a result of cultural convention (e.g., "Hound Dog" by Elvis Presley, "The Gambler" by Kenny Rogers, Beethoven's "5th Symphony," etc.); (b) are excepts of "real-life" recordings that include, in addition to the "to be recognized" melody line, a background of complex combinations of harmony played by one or more musical instruments playing simultaneously; and (c) represent one of three musical genres (styles): pop, classical, or country western. The listener may be able to draw on pitch, rhythm, and timbre (solo or blended instruments). In the case of the pop and country western genres, the items include song lyrics.

The complex song recognition task reflects to a greater extent than the simple melody task the musical stimuli heard in everyday life. Based on current-day implant characteristics, the rhythmic, timbral, and linguistic features of these complex song items are likely more accessible than is pitch information, the predominant feature of the simple melody task. However, one cannot presume that the additional information in the complex songs will assist the implant recipient. As noted earlier, some implant recipients report that they are most able to understand and enjoy music that they describe as "simple." It is possible that extracting the target melody line from the background sounds of a large orchestral accompaniment may be too difficult a figure-ground task, and that accompaniment may actually resemble background noise.

Complex Song Appraisal

Because song recognition is a skill associated with "normal" hearing, it is one indicator of successful device use, especially relative to pitch perception. However, given that music's primary functions are aesthetic enjoyment and entertainment, the extent to which music sounds pleasant (appraisal) is as important an indicator of implant benefit, possibly more so than is song recognition. Further, recognition is not required for appreciation. People with normal hearing acuity often enjoy music that they cannot identify by song title (e.g., enjoying a song played on the radio, without knowing the song title). Conversely, people may dislike musical selections that are easily recognizable. However, research indicates that normal hearing listeners prefer music in which they can adequately perceive patterns of redundancy and variation (as opposed to hearing a chaotic sequence of seemingly random sounds; Meyer, 1956). Furthermore, research indicates that normal hearing adults tend to prefer music that has an optimal level of complexity and familiarity. That is, music that is too complex or too simple is likely to be less pleasant (Cuddy & Upitis, 1992; Heyduck, 1975).

Objective complexity of a given musical selection may be determined by calculating the amount of variability or uncertainty associated with a given musical event. This quantification is directly related to the amount of information and redundancy within the event, which is then processed peripherally. However, relative to appraisal or liking of music, research with normal hearing persons indicates that subjective complexity of the stimulus is an important factor in musical taste (Cuddy & Upitis, 1992; Hargreaves, 1986; Heyduck, 1975; Radocy & Boyle, 1988). Subjective complexity is a function of the interaction between the objective complexity of the stimulus and the listener's musical knowledge, experience with the musical style and/or idiom, and familiarity with the particular musical stimulus (Radocy & Boyle, 1988). A classic model of musical appraisal, known as the optimal complexity model, indicates that listeners tend to appraise music more positively that is at an optimal, or intermediate, level of complexity.

However, the subjective complexity of a given musical selection can be modified by repeated exposure, training, or practice, which can lower the stimulus complexity and thus alter the affective value of the stimulus pattern (Radocy & Boyle, 1988). At least for normal hearing persons, the extent to which an individual appraises a given song in a positive manner will be influenced by the listener's prior listening experiences, both for overall styles, as well as prior exposure to specific musical pieces (i.e., familiarity; Berlyne, 1971; Bradley, 1971; Coffman, Gfeller, & Eckert, 1995; Gfeller, Asmus, & Eckert, 1991; Gfeller & Coffman, 1991; Hargreaves, 1984; Heyduck, 1975).

Anecdotally, implant recipients report that music that is too complex is more difficult to understand and less pleasant to hear. However, it is difficult to determine from informal comments what constitutes complexity for implant recipients. Furthermore, it is not known whether the relations between complexity and appraisal as seen in normal hearing adults also occur for implant recipients, who have atypical representation of music via the implant.

This study will examine the following: (a) the impact of structured musical training on recognition of simple melodies (familiar and unfamiliar songs introduced during training) presented in two forms of vertical complexity: melody versus melody plus harmony; (b) the impact of structured musical training on recognition of complex songs (familiar and unfamiliar songs introduced during training) representing three commonly heard styles of music: classical, country western, and pop; and (c) the impact of structured training on appraisal (liking) and perceived complexity of complex songs.

METHOD

Participants

Participants included 24 adults with postlingual deafness who had 12 to 15 months experience with a Nucleus CI24M implant. Participants were randomly assigned to either the control group (no training) or the training group. Nine of those assigned to the control group completed pre- and posttesting. Two additional participants initially assigned to the control group, who completed pretesting, were unable to return for posttesting after 3 months due to medical problems unrelated to the implant (e.g., knee replacement surgery). Eleven of the 12 participants assigned to the training program completed pretesting, the entire 3 month training protocol, and posttesting. The 12th individual assigned to the training group started the home training program but found that he was unable to read the written information that accompanied the musical stimuli due to very limited reading competency (the program requires a reading ability of approximately 4th grade level). He struggled through 2 weeks of the program, with the help of his granddaughter, who assisted him as often as possible with the written material. Although he stated that he enjoyed listening to the musical excerpts, the clinical research team determined that the effort required to complete all aspects of the program (reading written information and writing responses to the stimuli) seemed unrealistic, and he was excused from the study.

Participant characteristics (hearing history, age, speech perception scores, music listening habits, and past experiences) of those in the control and training groups appear in Tables 1 and 2. None of the participants in either group was a professional musician or had formal music instruction beyond high school as determined by administering the *Iowa Music Background Questionnaire* (Gfeller, Christ, et al., 2000).

The Training Program

The rationale, development, and content of the training program are described in detail in Gfeller, Witt, Kim, Adamek, and Coffman (2000). Those assigned to the training program completed 48 instructional modules (each approximately 30 min in length) in their homes presented via a laptop computer, external loudspeakers, CD, CD player, and a workbook to accompany the listening exercises on CD. The participants were asked to complete four instructional modules per week over a 12-week time period.

A crossover design was used in order to control for potential inherent differences in recognition difficulty among items (Trehub et al., 1985) and to test for generalizability of the trained to untrained but similar material. In order to facilitate that design, two forms of the program were developed: Form A and Form B. The programs were identical in basic type of content and format. However, each form included a different list of simple melodies and complex songs. Participants in the training program were randomly assigned to Form A or B.

Presentation of simple melodies. From a list of 24 simple melodies, half (12) of the items were included in Form A of the program, and half (12) were included in Form B. Six of the simple melodies in each form (A and B) were commonly known songs (e.g., "Happy Birthday," "Yankee Doodle," etc.), and six of the simple melodies were unfamiliar songs newly composed expressly for use in this training program. Unfamiliar songs composed using similar pitch and durational features as those in the familiar songs were included in the program to test whether implant recipients can learn to recognize previously unfamiliar songs for which they do not have the contextual cues, as is the case with previously famil-

Table 1

Characteristics of Participants: Descriptive Statistics

	Sex	Age	LPD	IA C	in N	IA C Hint	CNC
Control							
1	M	38	15.00	61.54	44.87	42.47	34.00
2	F	71	6.00	66.67	66.67	98.12	68.00
3	F	75	0.50	70.51	62.82	90.41	56.00
4	F	70	2.00	75.64	71.79	98.04	72.00
5	M	72	2.00	57.69	57.69	97.10	54.00
6	M	33	5.50	43.58	37.17	74.20	24.00
7	F	51	0.17	73.08	67.95	88.61	78.34
8	M	51	1.00	–	–	28.32	16.00
9	F	40	22.00	42.31	43.59	56.64	16.00
M		55.7	7.50	61.38	56.57	74.88	46.48
SD			9.89	12.79	13.01	26.34	24.28
Training							
1	F	38	7.00	–	–	88.68	59.00
2	F	42	21.00	–	–	51.15	30.34
3	M	70	10.00	41.02	19.23	–	–
4	M	60	12.00	62.82	66.67	97.12	32.00
5	M	46	33.00	–	–	36.85	19.34
6	F	53	35.00	55.12	56.41	99.06	58.00
7	F	52	3.00	55.12	47.43	72.64	22.00
8	M	72	4.00	75.64	70.51	81.80	54.00
9	F	42	19.00	56.41	70.51	87.62	18.00
10	F	75	4.00	64.10	61.54	98.15	56.00
11	M	73	10.00	37.18	32.05	35.40	12.00
M		56.6	7.20	57.69	56.41	75.12	32.40
SD			7.53	14.07	16.57	24.06	20.95

Note. Dashes indicate that data was missing. LPD = Length of profound deafness. IA C = Iowa Consonant Test. IA C in N = Iowa Consonant in Noise Test. Hint=Hearing in Noise Test. CNC = Consonant-Nucleus Consonant Word Recognition Test.

iar songs. In order to examine the effect of rhythmic cues on song recognition and training, the simple melodies in each form (A and B) included items that were highly rhythmic in character, and items that were essentially arrhythmic (equal note values).

More detail regarding stimuli selection and preparation is described in Gfeller, Witt, et al. (2000). The simple melodies presented in melody only and melody-plus-harmony versions, were presented via a laptop computer and external speakers. The stimuli were prepared using the acoustical piano setting of MIDI (Musical Instrument Digital Interface) software, which resembles closely the acoustical version of piano, a commonly-heard instrumental sound.

Research regarding music training programs devised for normal hearing adults indicates that repetition of information to be learned is the single most important factor in program effectiveness and enhanced music appreciation (Amen, 1977; Bradley, 1971). The benefits of spaced, as opposed to massed, rehearsal are also

Table 2

Musical Background of Individual Participants and Pre to Posttest Change

	Amount of musical training	Pre-implant listening habits	Post-implant listening habits	Change:[a] simple melody	Change:[a] complex song
Control					
1	–	–	–	0	0
2	2	–	5	0	0
3	1	5	2	0	0
4	1	3	3	3	3
5	2	4	3	0	4
6	2	6	5	0	7
7	2	8	5	11	16
8	1	4	2	-2	6
9	4	5	6	9	0
Training					
1	4	5	8	0	10
2	2	4	3	22	24
3	2	6	3	17	58
4	4	4	4	12	41
5	–	–	5	12	47
6	4	3	6	2	53
7	–	6	2	5	3
8	2	6	3	9	30
9	5	4	3	15	49
10	4	6	3	12	25
11	2	5	3	13	21

Note. Dashes indicate that data was missing.
[a]Change = Pre to posttest change in percent correct.

well established within the field of psychology (Sternberg, 1999). Therefore, repetitions of each simple melody were distributed over the 12-week time period. There were a total of 10 repetitions of each melody from either the Form A or Form B list. Because the melodies were not accompanied by lyrics, the listener had no linguistic cues to help with melody recognition.

In order to assist the listener with following the pitch changes, a visual representation of the melody and its title appeared on the computer screen as the melody was heard over the external loudspeakers. Thus, the listener could associate the pattern of pitches and rhythm as heard through their processor and implant with the song title and overall pitch contours presented on the screen. Each week, the final lesson included a brief review in which the participant was asked to discriminate or recognize the melodies presented during that week's lessons from a closed set of options.

Presentation of complex song excerpts. Stimuli selection and preparation are described in detail in Gfeller, Witt, et al. (2000). A total of 36 complex songs (18 presented in Form A, and 18 presented in Form B) representing classical, country western, and pop music was selected for the program. Those styles were selected because: (a) they are commonly-heard styles within everyday life (Hoffer, 1992) and (b) these are three styles identified as most preferred styles of music in surveys of implant recipients served by our research center, thus adding to the utility of this program content (Gfeller, Witt, et al., 2000). Specific item selection procedures are described in Gfeller, Witt, et al. (2000). A third of the items were representative of each genre (12 country western, 12 classical, 12 pop).

The complex songs included items considered highly familiar (i.e., well known by the general public although may not be known by a given individual) and items considered unfamiliar or obscure (i.e., representing one of the three genres but not well known to the general public). This categorization of items was performed to test the effect of prior familiarity on song recognition and appraisal. It is important to note that people are likely to be most familiar with songs from those styles of music they prefer and choose to listen to in everyday life. For example, people who prefer pop music are more likely to know generally well-known songs in that genre but may have little familiarity with best known items from other genres such as country western or classical. Thus, it is unlikely that even normal hearing people would recognize all 36 songs. However, pilot testing with normal hearing adults clearly differentiated among those items categorized as highly familiar (known by 75% or more of those tested) and those categorized as unfamiliar (typically known by less than 10% of those tested; Gfeller, Witt, et al., 2000).

Because songs vary considerably in length (e.g., orchestral symphonies can last a full hour while some pop tunes are only 2 or 3 min in length), equivalent exposure to each item was achieved by presenting a 3-min excerpt for each song item. The excerpt for each song was presented 11 times over the 12-week time period. The participant listened to three assigned excerpts per lesson using a CD player and external speakers. Each sound excerpt was accompanied by a brief written lesson in a companion workbook, which included a brief description of the music in that lesson. Because attention is an important prerequisite to recall of information, focused attention during listening was encouraged by the provision of brief exercises in the workbook. For example, the participants would be asked to describe briefly what they had heard, by using both adjective lists as well as open-ended questions about the quality of the sound.

Pre and Posttest Measures

Each participant (training group and control group) was pretested for simple melody recognition using the Familiar Melody Recognition Test, for complex song recognition using the Complex Song Recognition Test, and for complex song appraisal using the Complex Song Appraisal Test. These are subtests from the *Iowa Music Perception and Appraisal Battery* developed at The Iowa Cochlear Implant Clinical Research Center (Gfeller et al., 1998). No feedback was given on accuracy or appraisal ratings during testing.

Familiar Melody Recognition Test (simple melody recognition). The test for simple melody recognition is described in depth in Gfeller et al. (in press). Briefly, each familiar and unfamiliar item was presented in random order via a computerized test format. Instructions and prompts to listen were presented on the computer screen, and the sound files for each item were delivered via external speakers. The participant was prompted on the computer screen to listen while the melody item was played. After the item was completed, if the melody was unfamiliar, the participant pressed the "no" response on the touch-sensitive screen or pressed the "yes" response if the melody sounded familiar. If the participant pressed the "yes" response, then the participant received a prompt on the screen to identify the song. Because of the "tip-of-the-tongue" phenomenon that can occur during recall tasks (Sternberg, 1999), the test administrator used a structured set of prompts to elicit song identification of the title, song lyrics, or topic of the song (described in detail in Gfeller et al., in press). The response was keyed in by the test administrator, and the answer was automatically saved to a computer file. No feedback on accuracy was provided during testing.

Complex song recognition. The Complex Song Recognition Test included two practice items and brief excerpts (12-17 s long) extracted from the 3-min samples included in Forms A and B of the program. That is, the respondent was required to recognize the brief excerpt as part of a longer musical selection that they had been exposed to during training. Because implant recipients can sometimes recognize the verbal information in the lyrics, no excerpts were used that included the title of the song in the sung lyrics. The songs were presented in random order.

Instructions and prompts to listen were presented on the computer screen, and the sound files for each item were delivered via external speakers. The participant viewed prompts on the computer screen to "listen" while the song item was played. After the item was completed, the participant pressed the "no" response on the touch-sensitive screen to indicate if the song sounded unfamiliar, or "yes" if the song sounded familiar. If the participant pressed the "yes" response, then the test administrator used a structured set of prompts to elicit song identification of the title, artist/composer, song lyrics, or topic of the song. The response was keyed in by the test administrator, and the answer was automatically saved to a computer file. No feedback on accuracy or on the genre of each item was provided during the testing.

Because musical training and experience is unevenly distributed among the general population, it is possible that an individual may be unfamiliar with a specific song in the test despite the fact that it is well-known to the general public. In such an instance, failure to recognize the melody is not a function of auditory acuity but rather exposure. After completion of all the tests, participants were given an alphabetized list of 106 well known songs that included the names of the 24 simple melody titles and the 36 complex song titles from the test. They were asked to place a check next to each song title that they recalled hearing prior to deafness. Those items missed on the computerized test were cross-checked with the completed alphabetized list of songs to determine familiarity prior to deafness as described above. These data regarding individual familiarity with specific songs were used as part of the subsequent data analyses.

Complex song appraisal. The Complex Song Appraisal Test included two practice items and brief excerpts (12-17 s long) also used in the Complex Song Recognition Test (described previously). The songs were presented in random order. The participant viewed prompts on the computer screen to "listen" while the song item was played via external speakers. After each item was completed, a screen appeared with two visual analog scales (100 mm), one with bi-polar adjectives of *like - dislike* and the other with bi-polar adjectives of *simple - complex*. The participants touched that point on the visual analog scale that represented their opinion on these two variables. The response was automatically saved to a computer file.

Speech Perception Measures

The following measures of speech recognition were correlated with outcomes of recognition and appraisal: *Iowa Medial Consonant Test* (Tyler, Preece, & Tye-Murray, 1986), the Iowa recording of the *NU-6 Words Test* (Tillman & Carhart, 1966), the *Hearing in Noise Test (HINT)*, and the *Consonant-Nucleus Consonant Test (CNC)*.

Musical Background Questionnaire

The *Iowa Music Background Questionnaire* is described in detail in Gfeller, Christ, et al., 2000. Briefly, participants completed questionnaire items regarding any formal music instruction they received prior to hearing loss. The score for

Amount of Musical Training indicates the number of different types of music classes and length of participation (elementary school through post-secondary education) prior to hearing loss. The larger the score, the more varied and lengthy the instruction. Individuals with college training tend to score in the range of 20 points or higher. The score for Pre-implant Listening Habits is a quantification of the amount of time spent listening to music and self-reported musical enjoyment (Likert scale) prior to hearing loss (range of 2-8, with larger scores indicating more listening and greater enjoyment). The score for Post-implant Listening Habits is a quantification of the amount of time spent listening to music and self-reported musical enjoyment (Likert scale) following implantation (range of 2-8, with larger scores indicating more listening and greater enjoyment). Individual scores for musical training and experiences appear in Table 2.

Treatment Phase of the Study

Following pretesting, those participants assigned to the training group were given instructions on how to use the training program equipment. They were asked to complete all 48 lessons in the program at home over a period of 3 months and to then return for posttesting. All participants in the training program were given a brief phone call every 2 weeks to check on continued compliance with the program and to ensure that there were no technical difficulties with the equipment. With the exception of the one participant with literacy problems, all those assigned to the training program completed the 48 lessons.

Following pretesting, those in the control group were scheduled for posttesting 3 months later. The control condition included only incidental exposure to music through their normal routine. The two groups (training and control) were compared on changes in recognition accuracy and appraisal ratings from pre to posttest.

RESULTS

The data were analyzed using a mixed general linear model (repeated measures design) and *t* tests for pairwise comparisons. Test results were correlated with individual characteristics of age, hearing history, musical background, and speech perception scores.

Simple Melody Recognition

Figure 1 shows the mean scores (percent correct) for pre and posttests on simple melody recognition. Analysis of variance and post hoc analyses revealed a significant difference between the posttest scores of the control and the training group ($p < .02$). There was, however, no significant change from pre to posttest for either group for simple melody recognition. There was considerable variability in pre to posttest change among individual training participants (see Table 2).

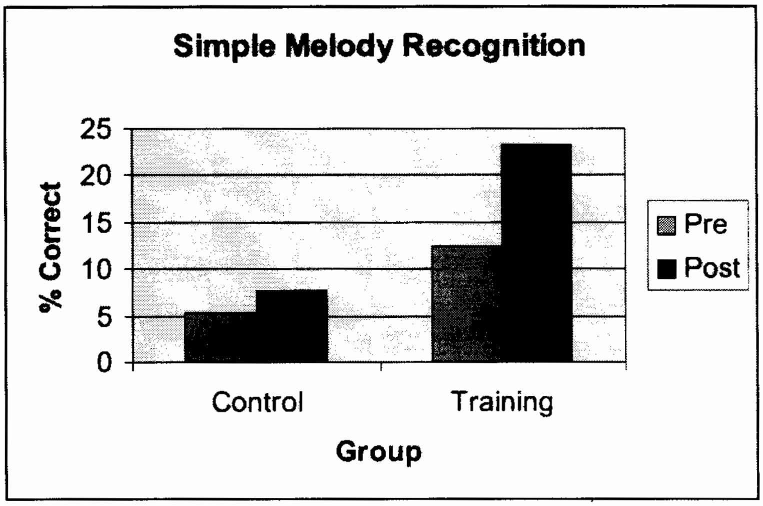

Figure 1. Simple Melody Recognition – Percent Correct. The mean score for the control group in pretesting was 5.33 ($SD = 4.74$); in posttesting the mean score was 7.67 ($SD = 8.06$). The mean score for the training group in pretesting was 12.45 ($SD = 13.13$); in posttesting the mean score was 23.36 ($SD = 14.40$).

Further item analyses were conducted to better understand what aspects of music listening were most amenable to structured training. The data for the training group were analyzed for variables of vertical complexity (melody alone vs. melody plus harmony), rhythmicity (rhythmic vs. arrhythmic items), and familiarity (familiar vs. unfamiliar). Although implant recipients often report anecdotally that they find it easier to understand "simple" music, the addition of harmony to the melodies, which increases vertical complexity, did not seem to detract from song recognition. During pretesting, those assigned to the training group achieved a mean score of 2.6 items correct in the melody only condition and a mean score of 2.7 items correct in the melody plus harmony condition. In posttesting, the training group achieved a mean score of 5.05 items correct in the melody only condition and a mean score only slightly smaller ($M = 4.54$) for items in the melody plus harmony condition.

During pretesting, those assigned to the training group achieved a mean score of 2.9 items correct for rhythmic items and 2.6 items correct for arrhythmic items. In posttesting, the training group achieved a mean score of 5.6 items correct for rhythmic items and a somewhat smaller mean score of 4 items correct for arrhythmic items.

Only 5 of the 11 participants in the training program were able to recognize in posttesting any of the unfamiliar (i.e., newly composed) items that were presented in their training program. Those gains were very modest (range of 1 to 4 unfamiliar items learned, $M = 1.8$), despite the fact that training participants received equal exposure during training to familiar and unfamiliar items. It seems that learning new songs having essentially pitch and rhythmic cues is a very difficult task with present-day speech processing strategies.

It is important to note that participants in the training group showed greater recognition on those melodies that had been included in their assigned form (A or B) of the training program. That is, those assigned to Form A tended to recognize those items from the A program, and those assigned to Form B tended to recognize those items from the B program. Thus, instruction can help implant recipients to relearn the new sound of previously known songs (paired associate learning). However, participants often noted that it was challenging to identify even those simple melodies that had been included in the training program. Thus it appears likely that for most participants, change in accuracy was not the result of improvement in fundamental perceptual ability for pitch perception but rather a matter of developing compensatory strategies for recognition.

Correlations between simple melody recognition and speech scores were weak (ranging from $r = .06$ to $r = .29$). Correlations with age, length of profound deafness, musical background, and speech scores vary in strength and appear in Table 3.

Complex Song Recognition

Analysis of variance revealed significant interactions of group (control vs. training) by pretest to posttest change ($p < .0001$). Figure 2 shows the mean scores (percent correct) for complex song recognition. Post hoc analyses reveal the sources of differences: There was a significant difference ($p < .0001$) between the posttest scores of the control and training groups, and the training group achieved a significant change from pre to posttest ($p < .0001$).

Item analyses were conducted in order to better understand what aspects of music listening were most amenable to structured training. The data for the training group were analyzed for genre (styles of pop, country, and classical music) as well as familiarity (familiar vs. unfamiliar presented in the training program). With regard to genre, during pretesting, the mean number of items correct for each genre was less than 1 item out of a possible 12 items per category (0.80 for pop music; 0.45 for classical music; 0.90 for country western music). Following training, implant recipients showed greater recognition of country western ($M = 4.55$) and pop ($M = 4.18$) styles than classical ($M = 2.90$).

Comparisons of those songs accurately identified with those listed in the alphabetized list of songs as familiar prior to deafness indicated that 10 of the 11 training participants were able to accurately recognize between 2 to 11 ($M = 4.36$ items) complex songs that were unfamiliar prior to implantation. Thus, it appears that the implant transmits enough salient cues from the complex songs to permit

Table 3
Correlations Between Simple Melody Recognition, Complex Song Recognition, and Participant Characteristics

	Simple melody recognition	Complex song recognition
Age		
Control	-0.29	-0.25
Training	-0.30	0.10
LPD		
Control	0.50	-0.43
Training	0.48	0.54
MT		
Control	-0.07	-0.33
Training	0.66	0.37
Pre LH		
Control	0.79	0.66
Training	-0.37	-0.63
Post LH		
Control	0.43	0.21
Training	-0.09	0.03

Note. LPD = Length of profound deafness. MT = Music training pre-implant. Pre LH = Pre-implant listening habits. Post LH = Post-implant listening habits.

learning new songs post implantation. In addition to recognizing significantly more complex songs, many training participants noted that they had improved in ability to recognize the style of individual items (country western, classical, pop) even if they could not recognize the exact song title.

Relations among variables. Correlations between speech perception scores and percent correct were weak ($r = .03$ to $.29$). There was a strong positive correlation ($r = .69$) between recognition scores for the simple melody recognition and complex song recognition.

Complex Song Appraisal

Liking. An analysis of variance revealed significant interactions of group by pre versus posttest ($p < .0001$) on the variable of appraisal, or liking. Those items categorized as highly familiar to the general public received significantly more positive appraisal ($p < .003$) than did the obscure items. The training group showed significantly more positive ratings than did the control group on posttest appraisal ratings ($p < .0001$). Furthermore, the training group showed a significant positive change in appraisal ratings from pre to posttesting ($p < .0001$). *T* tests revealed significantly more positive liking in posttests for the training

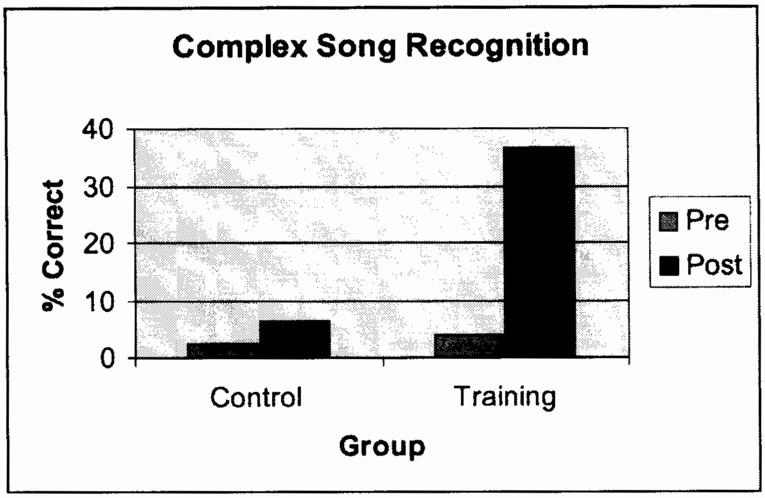

Figure 2. Complex Song Recognition – Percent Correct. The mean score for the control group in pretesting was 2.56 ($SD = 4.50$); in posttesting the mean score was 6.22 ($SD = 9.48$). The mean score for the training group in pretesting was 3.73 ($SD = 4.34$); in posttesting the mean score was 36.45 ($SD = 19.21$).

group for both familiar ($p < .0001$) and obscure ($p < .05$) items. There were no significant differences between appraisal scores for those songs in Form A and Form B of the program or for the three different genres (country western, classical, pop).

Complexity. A lower complexity rating indicates greater ease in following or understanding the sequence of sounds. Therefore, a lower posttest score is the desired effect of treatment. On the variable of complexity, there was no significant difference at the .05 confidence level. Pre to posttest change for the training group approached significance at $p < .06$. Changes in liking and complexity from pre to posttest appear in Figures 3 and 4. Means and standard deviations for the three genres appear in Table 4. Means and standard deviations for familiar and unfamiliar songs appear in Table 5.

Relations among variables. An overall correlation (both groups, pre and posttest scores) between liking and complexity was $r = -.38$. The correlation between liking and complexity for the posttest scores were $r = -.22$ for controls and $r = -.51$ for the training group. Pearson correlations revealed weak relations between appraisal and the following variables: amount of musical training (classes) prior to hearing loss, music listening habits pre and post implant, age, length of profound deafness, and those speech scores described above. In addition, there was a moderate negative correlation ($r = -.41$) between complex song appraisal and complex song recognition.

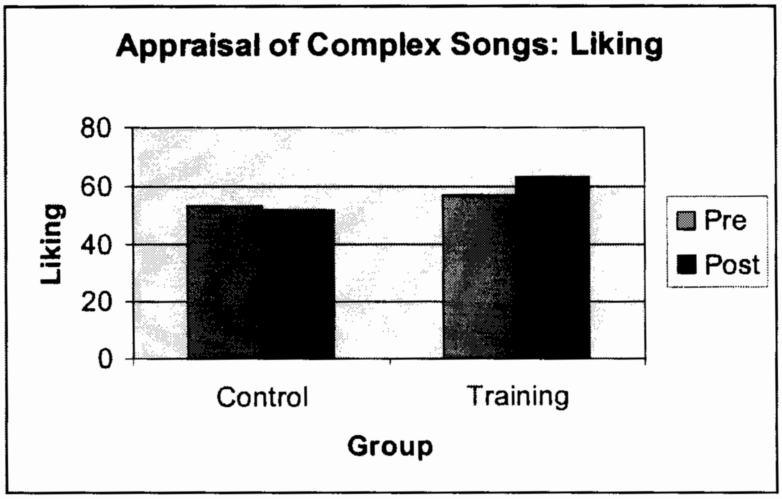

Figure 3. Appraisal of Complex Songs: Liking. The mean score for the control group in pretesting was 52.98 ($SD = 24.97$); in posttesting the mean score was 51.23 ($SD = 25.60$). The mean score for the training group in pretesting was 56.14 ($SD = 23.18$); in posttesting the mean score was 62.52 ($SD = 21.99$).

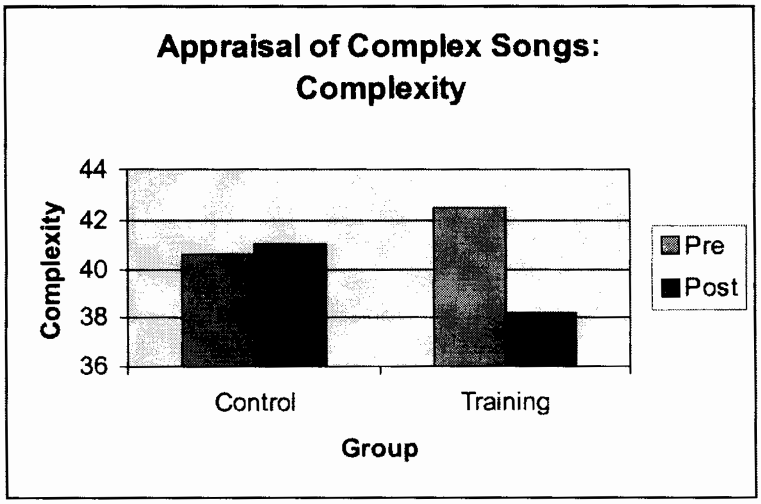

Figure 4. Appraisal of Complex Songs: Complexity. The mean score for the control group in pretesting was 40.64 ($SD = 23.93$); in posttesting the mean score was 40.99 ($SD = 25.86$). The mean score for the training group in pretesting was 42.47 ($SD = 23.02$); in posttesting the mean score was 38.19 ($SD = 23.83$).

Table 4

Means and Standard Deviations for Genres: Liking and Complexity

	Control		Training	
	Pre	Post	Pre	Post
Country				
Like	60.40 (22.13)	58.24 (21.66)	53.46 (22.61)	63.67 (20.04)
Complexity	35.62 (21.25)	32.96 (20.68)	36.77 (20.24)	30.86 (19.47)
Classical				
Like	39.94 (24.07)	35.88 (25.41)	54.29 (23.65)	63.84 (22.70)
Complexity	46.30 (24.86)	45.73 (28.84)	49.76 (25.51)	46.30 (26.13)
Pop				
Like	58.77 (23.47)	60.08 (22.15)	57.64 (23.23)	59.95 (23.14)
Complexity	39.98 (24.54)	44.08 (25.61)	40.97 (21.26)	37.41 (23.12)

Table 5

Means and Standard Deviations for Familiar Versus Unfamiliar Items: Liking and Complexity

	Control		Training	
	Pre	Post	Pre	Post
Familiar				
Like	54.07 (24.32)	52.09 (26.31)	56.28 (22.16)	64.53 (21.44)
Complex	38.99 (23.60)	39.86 (26.32)	42.70 (22.38)	37.99 (23.94)
Obscure				
Like	50.80 (26.20)	49.47 (24.11)	52.86 (25.01)	58.59 (22.60)
Complex	43.95 (24.37)	43.32 (24.87)	42.04 (24.36)	38.56 (23.69)

DISCUSSION

These data suggest that structured training can significantly improve music perception and appraisal for some, but not all, aspects of music listening. These data suggest that benefit from training depends in part on the particular structural features of the given musical stimuli and whether or not that implant transmits an adequate signal of that feature to support learning and perceptual remediation. In particular, recognition of simple melodies made up primarily of pitch and rhythmic patterns, a task which is quite easy for normal hearing adults (Smith et al., 1994), is an especially difficult task when heard through speech processors. Although implant recipients are able to improve recognition of previously familiar songs to some extent, it is likely that most rely heavily on rhythmic cues for recognition and that improvement is the result of compensatory strategies rather than fundamental remediation of pitch perception. Patients who showed the greatest improvement may be those who enjoy a more normal relationship between frequency and pitch (Dorman et al., 1990; Gfeller et al., in press) or those who have greater ability to commit new material to memory (paired associate memory). Further testing is required to test these hypotheses.

Patient comments following completion of the training program indicate personal satisfaction with "relearning" some previously familiar songs. However, the remediation of fundamental perceptual skills would have greater general benefit. It is possible that this training protocol was not optimal for this type of listening task. However, given that normal-hearing adults typically improve perceptual accuracy with similar training (e.g., ear training in music theory classes), it is more likely that current-day devices do not transmit an adequate representation of pitch to support training and that more "normal" melody recognition will require a processor that transmits a more faithful representation of pitch.

It is interesting to note that implant recipients had similar recognition accuracy for songs accompanied by harmony as those presented in melody-alone format. These findings seem contrary to anecdotal reports by implant recipients that "simple" music is easier to follow.

It is encouraging to see significant improvement in both recognition and appraisal of complex songs, particularly because those stimuli are most representative of the kinds of musical sounds an implant recipient is likely to encounter in every-day life. Especially positive is that most participants in the training group were actually able to recognize and enjoy some previously unfamiliar complex songs. It is interesting to note that structurally complex songs are actually easier than simple melody patterns to recognize, contrary to anecdotal reports regarding perception of simple or complex musical sounds by implant recipients. This emphasizes the difficulty in interpreting verbal reports not accompanied by testing with actual musical stimuli.

Change in individual scores from pre to posttesting (see Table 2) shows the considerable variability from one implant recipient to the next in response to training. It is worthy to note that Participant #7 in the training group complained of ill health during posttesting. Immediately after posttesting, she was diagnosed with an infection, and she was immediately hospitalized for the period of a week. Participant #1 has Meniere's disease in addition to her hearing loss. She complained that her symptoms were particularly unpleasant during posttesting and told the test administrator that she felt her performance that day was not representative of her ability. While re-testing of these individuals would have been optimal in order to confirm whether their posttest scores were depressed because of ill health, participants were not available for an additional trip to the center.

Although improvement in accuracy and appraisal are the key outcome variables, it is also important to consider client satisfaction in the evaluation of any rehabilitation program. Literature regarding adult learning (Gfeller, Witt, et al. 2000; Merriam & Caffarella, 1999) indicates that adults persist in learning when the material is personally meaningful and can be readily applied to everyday life. Evaluations of the program regarding its format and content by the implant recipients (reported in greater depth in Gfeller et al., in press) indicate that the material to be learned was considered interesting and useful. All 11 who completed the program agreed that they would recommend the program to other implant recipients. The fact that 11 of the 12 participants randomly assigned to the program complied with the 3-month program is yet another indication of the utility of this program.

Unsolicited correspondence from several of the training participants highlights the personal and sociocultural benefits of the training program. One training participant, in Week 11 of the program, spontaneously e-mailed our team to share her delight in improved music listening. She wrote:

> I just returned from a Christmas Concert last night. . . . When they sang "Do you hear what I hear?" I was even more overcome with emotion than the first time [after I was first hooked up]!! ALL the music was enjoyable, including brass and piano instrumentals. Hallelujah!!

Another implant recipient sent the following e-mail message: "Now that I have completed the music training program, I wish to express appreciation for the opportunity to participate. . . . I do feel that the program was very beneficial." The wife of yet another training program participant said that her best Christmas present this year was walking into the living room and seeing her husband once again listening to and enjoying orchestral concerts on public television, "just like he used to." While musical enjoyment does not have the obvious adaptive value (e.g., essential to survival in work and home) that we associate with speech and language, music has a prominent place in society nevertheless and contributes to social integration as well as overall quality of life. These anecdotal comments by training program participants illustrate potential benefits beyond accuracy scores, namely greater social integration that can result from enhanced appreciation of music through the implant.

In summary, these data indicate that some aspects of music listening can be improved with training, even with current-day speech processors which are less than optimal in transmitting salient features of music. Rehabilitative audiologists can assist implant recipients who are interested in greater music enjoyment by targeting music listening tasks that are more amenable to rehabilitation and by helping them to set more realistic expectations for listening enjoyment. Improvement does require focused and repeated listening exposure, and at present, some types of music are likely to sound better than others. Important changes in signal processing are most likely necessary before implant recipients will be able to enjoy music as easily as do normal hearing adults. Perhaps greater improvement on pitch-based tasks (i.e., melody recognition) will be possible with future upgrades in signal processing that result in more normal pitch perception.

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