Musical Backgrounds, Listening Habits, and Aesthetic Enjoyment of Adult Cochlear Implant Recipients

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Abstract
This paper describes the listening habits and musical enjoyment of postlingually deafened adults who use cochlear implants. Sixty-five implant recipients (35 females, 30 males) participated in a survey containing questions about musical background, prior involvement in music, and audiologic success with the implant in various listening circumstances. Responses were correlated with measures of cognition and speech recognition. Sixty-seven implant recipients completed daily diaries (7 consecutive days) in which they reported hours spent in specific music activities. Results indicate a wide range of success with music. In general, people enjoy music less postimplantation than prior to hearing loss. Musical enjoyment is influenced by the listening environment (e.g., a quiet room) and features of the music.

Key Words: Cochlear implants, listening habits, music enjoyment, timbre

Abbreviations: HIGH = high school, POST = adult education, PRIM = primary school, SCT = Sequence Completion Test, SE = standard error, TERT = tertiary, VMT = Visual Monitoring Task, VMT1 = Visual Monitoring Task one per second rate, VMT2 = Visual Monitoring Task two per second rate.

The cochlear implant is an assistive hearing device that has been designed primarily for persons who are profoundly deaf and who receive little or no benefit from traditional hearing aids. Over the past two decades, considerable information has been amassed about the extent to which the various device types or coding strategies facilitate verbal communication. Because the device has been designed primarily for speech perception, it is not particularly surprising that little research has been conducted to date regarding the extent to which music is accurately perceived or enjoyed by adult implant recipients. However, music is a pervasive art form and environmental sound. Consequently, music perception and enjoyment seem reasonable topics for systematic inquiry in the context of evaluating the impact of implants.

Existing research on music perception and enjoyment of adult implant recipients suggests that some features of music are more effectively transmitted via the implant. For example, studies investigating the rhythmic perception of adult implant recipients indicate that they are less accurate than normal-hearing adults on temporal perception tasks presented at rates that push the auditory system (Gfeller et al, 1997). However, these same recipients demonstrate accuracy of discrimination similar to that of normal-hearing adults when simple rhythm patterns are presented at moderate tempi (Gfeller and Lansing, 1991, 1992; Gfeller et al,
Thus, with regard to typical music listening experiences, implant recipients are able to perceive with reasonable accuracy much of the basic meter (beat) and rhythmic patterns. Whereas rhythmic patterns are transmitted fairly faithfully through the present generation of implants, that is not the case for pitch sequences (melodies). Implant recipients are significantly less accurate than are normal-hearing adults for perception of simple melodic patterns (Gfeller and Lansing, 1991, 1992; Gfeller et al., 1997; Pijl, 1997), and accuracy for pitch percepts varies considerably from one implant recipient to the next (Dorman et al., 1991). Implant recipients also differ significantly from normal-hearing adults with regard to timbre (tone quality of instruments) recognition and enjoyment (Gfeller et al., 1998a). More specifically, implant recipients are less accurate in identifying from sound alone commonly heard orchestral instruments (i.e., violin, piano, clarinet, and trumpet). Further, their ratings of the sound quality are generally lower and more restrictive in range than are the ratings by normal-hearing adults.

Because pitch and timbre are such important structural features of music, these research findings imply that musical enjoyment may well be an unrealistic outcome for implant recipients and that implant recipients might avoid or forego those situations that involve considerable music listening. In fact, some recipients implanted at The University of Iowa have expressed disappointment or frustration about how music sounds through their implant. However, one cannot assume that personal enjoyment of music is a function only of accuracy of perception. Anecdotal reports from other implant recipients, as well as articles in implant user magazines, indicate that some implant recipients do enjoy music, despite the technical features of the present generation of devices.

Anecdotal reports of music enjoyment, although interesting, should not be assumed to represent the general population of implant users with regard to perceptual accuracy or appreciation of music postimplantation. Therefore, the purpose of this study was to systematically gather information from a representative sample of implant recipients that would accurately reflect the experiences of implant recipients with regard to musical involvement and enjoyment postimplantation. More specifically, the study was designed to determine whether cochlear recipients enjoy and engage in musical activities and whether their backgrounds, prior involvement in music, audiologic success with the implant, and preimplant attributes are associated with reports of music participation.

In order to answer these questions, two studies were conducted: study 1 administered a questionnaire to experienced adults who received a cochlear implant at the Iowa Cochlear Implant Clinical Research Center, and study 2 was designed to assess participation in music-related activities by recent implant recipients and long-term implant users with a daily diary following the recommendations of Tye-Murray et al. (1993).

STUDY 1

Method

Participants

Potential participants included 70 consecutively implanted adults who had received a multichannel cochlear implant at The University of Iowa as part of the National Institute on Deafness and Other Communication Disorders (NIDCD) grant-supported Iowa Cochlear Implant Clinical Research Center. To be eligible for an implant in this program, participants were required to be at least 18 years of age, have a postlingually acquired bilateral profound deafness (minimum 95 dB HL), and receive no measurable benefit from hearing aids. Additionally, they participated in annual follow-up assessments that provided audiologic outcome measures. It was in the context of the routine annual follow-up assessments that participants were contacted by letter and invited to participate in the current study, all who are active participants in our center’s research program.

Sixty-five implant recipients (94% response rate) completed and returned the questionnaire. This group included 35 females and 30 males ranging in age from 29 to 80 years of age (mean = 57.63, SD = 14.99). Length of profound hearing loss ranged from less than 1 year to 58 years (mean = 11.82, SD = 12.63). There were 29 Clarion, 17 Nucleus, 11 MED-EL, and 8 Ineraid users; length of implant use ranged from 33 months to 142 months (mean = 85.69, SD = 33.21).

Questionnaire

The questionnaire used for this study, the Iowa Musical Background Questionnaire (Gfeller et al., 1998b), was a modified and expanded version of a questionnaire used in prior research by Gfeller and Lansing (1991, 1992). Additional
questions were added regarding formal musical training, the enjoyment of specific musical instruments and musical styles, and particular environmental circumstances that may influence the quality of musical sound. These additional questions were developed after interviewing implant recipients (N = 35) in our own clinic and through a survey published in CONTACT, an international magazine expressly for implant recipients. The survey consisted of open-ended questions regarding musical involvement and enjoyment. The responses were coded for prominent themes and objective multiple-choice questions relevant to the purposes of this study were developed (Gfeller, 1996, 1998; Gfeller et al, 1997). Other portions of the questionnaire focused on attitude or personal preferences regarding particular types of musical sounds. Attitudes were measured using Likert-type scales, visual analog scales, and open-ended questions.

A draft of the expanded questionnaire was given to three audiologists and three implant recipients, who evaluated the document for clarity, appropriateness, and comprehensiveness of the items. A second draft of the questionnaire was completed and was then reviewed once again by two audiologists, three adult implant recipients, and four professionals involved in the research and design of cochlear implants. The final version of the questionnaire consisted of 21 items including multiple-choice questions, Likert-type rating scales, visual analog scales, and open-ended questions.

Speech and Cognitive Measures

To determine whether music listening and participation were related to the demographic characteristics of the participants or their audiolinguistic performance with the implant, survey data were correlated with the following measures: age, length of profound deafness, length of implant use, and speech perception measures. The speech perception measures included audition-only versions of the Consonant Test with and without noise, the Iowa Sentence Test (Tyler et al, 1986), the Vowel Recognition Test (Tyler et al, 1986), and the Northwestern University Auditory Test No. 6 (Tillman and Carhart, 1966). Because most of the implant recipients have multiple measures of speech perception over time, we selected the speech perception data as follows: all audiolinguistic tests for as long as 4 years prior to participating in the survey were averaged to reduce test variation. This also reduced the possible impact of missing data that would have occurred by using data points from one particular testing appointment.

Because both timbral recognition and speech perception by implant recipients were predicted by a number of experimental cognitive measures administered prior to implantation (see Gfeller et al, 1998; Knutson et al, 1991), scores from those measures were correlated with selected music questionnaire scores. The cognitive measures used were originally included to assess several specific attentional and cognitive abilities. These tests consist of a Visual Monitoring Task (VMT) and a Sequence Completion Test (SCT). The VMT, as a test of attention, reaction time, and working memory, requires that the subject observe a computer screen as numbers are displayed at either a one per second rate (VMT1) or a two per second rate (VMT2). When the displayed number reflects an even-odd-even pattern, the subject is required to strike a key on the computer keyboard. The score from the VMT is a standardized signal detection score that incorporates accurate responding (true positives and true negatives) and inaccurate responding (false positives and false negatives). The score from the SCT is based on the work of Simon and Kotovsky (1963) and reflects the number of sequences correctly identified in a fixed time period. As a measure of associative memory, participants are required to correctly identify the numbers that are associated with 12 two-dimensional geometric forms, with the score reflecting the number of trials to mastery and the mean number of correct identifications across 10 trials.

Results

Musical Background and Listening Habits

Musical Training Prior to Hearing Loss. Six questionnaire items focused on formal musical training prior to hearing loss, including participation in music lessons, musical ensembles (e.g., band, choir, and orchestra), and music classes (e.g., general music classes, music appreciation or theory, etc.). Respondents were asked to list the number of years of training for each category of musical training (e.g., music class, orchestra, etc.). In addition, respondents were to choose one of five descriptions that best matched their self-assessment of exposure to and experience with music. The five response options ranged from no formal music training or
knowledge about music to extensive formal training and considerable knowledge about
music.

A total score for formal musical training prior to hearing loss was determined as follows:
to reduce colinearity among the many training variables, the years of training were summed
into four time categories: (primary school) PRIM, (high school) HIGH, (tertiary) TERT, and (adult
education) POST. Two individuals, however, reported an extremely high number of years
training for the TERT and POST variables (12 and 20 years). Since most respondents listed
zero years in these variables, the values for these two individuals were truncated to a level
beyond the range of the other participants (2 years in the case of TERT variables and 3 years
in the case of POST variables). This allowed a reflection of years of training noticeably higher
than any other respondent without creating wildly outlying and highly influential values
for the overall score. Factor analysis revealed two significant factors, namely, PRIM and an aver-
gage of HIGH, TERT, and POST. The categorization of musical training into these two factors
(PRIM and the combined score of HIGH, TERT, and POST) seems quite appropriate from a cur-
ricular standpoint in that primary school music is often general in nature and emphasizes expo-
sure to music and enjoyment of music, whereas high school, tertiary, and adult education are
more likely to include participation in musical ensembles that required advanced musical train-
ing and skill development. Musical involvement in high school and beyond is more likely to be
an elective activity (thus, self-selection becomes a stronger factor in participation) than is par-
ticipation in elementary school music classes.

The range of scores for formal musical training during the elementary school years ranged
from 0 to 27 (mean = 6.15, SD = 6.22), with higher scores indicating several years of expe-
rience in multiple musical activities (e.g., participation in band, general music, and choir
throughout elementary school). The range of scores for formal musical training in high school,
college, or after college was 0 to 4.67 (mean = .77, SD = 1.14). Table 1 presents the breakdown
of global assessment of musical training, knowl-
dege, and experience. Seventy-seven percent
indicated that they listened to or were involved
in musical activities prior to hearing loss.

**Listening Habits.** A Likert-type scale (1 point
for strongly disagree to 4 points for strongly
agree) was used to ascertain to what extent
these implant recipients would describe them-
selves as persons who often chose to listen to
music. One item solicited their interest in music
prior to hearing loss and another item their
musical interest postimplantation. Next, they
were to indicate how much they typically listened
to music prior to hearing loss and then after
becoming accustomed to their implant. They
indicated the amount by selecting one of four cat-
ergories of listening time per week (e.g., 1 point
= 0–2 hours weekly, 4 points = 9 or more hours
of listening weekly). These two items (attitude
and listening habits) were combined to create a
score for music listening habits prior to hearing
loss (range of 2–8 points) and another score for
postimplantation (range of 2–8 points). The
mean score for listening habits prior to hearing
loss was 5.29 (SD = 2.02). The mean score for lis-
tening habits postimplantation was lower, at
4.11 (SD = 1.94).

**General Assessment of Satisfaction
with the Device for Music Listening**

An overall score for satisfaction regarding
how music sounds postimplantation, as com-
pared with recollection of how music sounded
prior to hearing loss, was obtained from a sin-
gle seven-choice questionnaire item. Possible
responses ranged from no interest or enjoyment
before or after implantation to considerable
enjoyment after implantation. The seven items
were combined into three general categories:
(a) 23 percent indicated little satisfaction in
music listening prior to or after implantation,
(b) 43 percent reported that the sound of music
is improving over time or is better than no music
at all (although less pleasant than before hearing
loss), and (c) 23 percent noted that music now sounds as pleasant as before hearing loss, or more so. The general listening satisfaction scores were then correlated with musical background, listening habits, age, hearing history, and speech and cognitive measures. Significant correlations were found between general enjoyment of music and the following measures: postimplant listening habits ($r = .73$, $p \leq .00$) and age ($r = -.42$, $p \leq .00$). No significant correlations were obtained for musical background, preimplant listening habits, length of profound deafness, length of implant use, or any of the speech measures.

Adjective Descriptors of Music

The overall quality of musical sound heard through the implant was assessed using seven 100-mm visual analog scales, each anchored with bipolar adjectives. The bipolar adjectives were selected in response to empirical data on adjective descriptors for musical sounds (Von Bismarck, 1974; Pratt and Doak, 1976), as well as prior feedback from implant recipients regarding the quality of musical sounds through the implant. The adjective pairs were as follows: like-dislike, pleasant-unpleasant, natural-mechanical, clear-fuzzy, sounds like music-does not sound like music, easy to follow-difficult to follow, and simple-complex. Figure 1 shows the mean values obtained for the seven adjective pairs.

Scores on the positive pole (maximum of 100) of the adjective pairs were then correlated with age, length of profound deafness, length of implant use, musical background, listening habits, and speech and cognitive perception measures. Table 2 provides a matrix of correlations for those measures that result in a large proportion of significant correlations. As can be seen, age, listening habits (especially postimplant listening), and speech perception measures were those significantly correlated with the largest number of positive adjective descriptors. There were no significant correlations for length of profound deafness and length of implant use and few isolated significant correlations with musical training and cognitive measures. The overall pattern of the latter correlations seems most consistent with a type I error.

Enjoyment of Musical Styles

A number of implant recipients have reported informally that particular styles of music sound better than others with the implant or have noted changes in style preference postimplantation (Gfeller et al, 1996b; Gfeller, 1998).

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Correlation Matrix for Adjective Descriptors, Age, Preimplant Listening Habits, Postimplant Listening Habits, and Selected Speech Perception Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pleasant</strong></td>
<td><strong>Like</strong></td>
</tr>
<tr>
<td>$r$</td>
<td>$p$</td>
</tr>
<tr>
<td>Age</td>
<td>-.500 ***</td>
</tr>
<tr>
<td>Preimplant habits</td>
<td>.273 *</td>
</tr>
<tr>
<td>Postimplant habits</td>
<td>.712 ***</td>
</tr>
<tr>
<td>IA Consonant Test Noise</td>
<td>.255</td>
</tr>
<tr>
<td>IA Consonant Test Sentence Test Noise</td>
<td>.216</td>
</tr>
<tr>
<td>Sentence Test</td>
<td>.411 *</td>
</tr>
<tr>
<td>NU-6 words</td>
<td>.244</td>
</tr>
</tbody>
</table>

* = <.05, **<.001, ***.0001.

$r$ = correlation, $p$ = p value, $n$ = number of participants responding.
Therefore, the questionnaire included pre- and postimplantation preferences for 11 specific and commonly heard musical genre (e.g., country and western, pop, classical; Gfeller et al, 1996a; Hoffer, 1992) that tend to have particular and typical structural characteristics with regard to rhythm, harmonic structure, instrumentation, and melody. For example, country and western often includes a simple melody line sung by a vocalist (consequently, the individual may be able to extract words), a clear and predictable beat, and a relatively simple, repetitive, and predictable harmonic structure. In contrast, many classical selections are played by large orchestras, have no vocal parts, and tend to have complex harmonic, melodic, and rhythmic structures.

In analyzing possible shifts in music style preference, a simple chi-square analysis of marginal distributions is inappropriate due to an inherent association between the pre- and postimplant responses. Because the music preference responses had intrinsic ordering (strongly dislike, dislike, like, strongly like), the use of a proportional odds cumulative logit analysis is appropriate for testing such a preference shift. The association between pre- and postimplant responses for any particular music type was predicted to be strong. That is, if a participant had a strong preference for a particular style of music prior to implantation, then that participant would be much more likely to have similar preference after implantation rather than changing to the other extreme. This assumption is easily justified because of the influence of family, friends, personal habits, and enduring opportunities for exposure. Due to this predicted strong association between pre- and postimplant responses, a linear-by-linear association model was fit to each music style. This choice, in effect, assumes that most of the responses are going to be along the diagonal (i.e., a participant's preferences pre- and postimplant would be close to the same), whereas the corners opposite the diagonal will have few, if any, counts. Although this association structure is important for the estimation of model parameters, there is greater interest in assessing shifts up or down in the marginal distributions. Therefore, an unrestricted association was also fit to the data, giving similar but slightly deflated results in regard to the marginal shifts measured. Table 3 contains results for each individual style. Participant responses fit the association and marginal components reasonably well. Although about half of the odds proportions were not significantly different from 1, the fact that they were all positive provides some evidence that there was a consistent shift downward in appreciation of musical styles from pre- to postimplant. Although the fitted model can account for possible strong associations between pre- and postimplant responses for a single style, there is no account for associations between styles. For example, if participants have different interpretations of the rating scale, participants common to any pair of styles changes would inflate the standard

An odds proportion greater than 1 denotes a shift downward in the appreciation of a given musical style from pre- to postimplant. As the odds proportion increases, the magnitude of the shift rises accordingly. A confidence interval that contains 1 reflects the lack of a statistically significant shift in appreciation from pre- to postimplant.

As an example of interpreting the above table, we would say that for pop music, the odds of a level 1 or lower response postimplant is 2.57 (1.17 to 5.65) times higher than the odds of a level 1 or lower response preimplant, for j = 1 (strongly dislike), 2 (dislike), 3 (like). Note that since there are only four levels, looking at level four or lower would include all respondents.

Table 3  Musical Style Preference, Pre- and Postimplantation

<table>
<thead>
<tr>
<th>Music Type</th>
<th>Odds Proportion</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pop</td>
<td>2.57</td>
<td>(1.17, 5.65)</td>
</tr>
<tr>
<td>Rock</td>
<td>1.99</td>
<td>(1.11, 3.58)</td>
</tr>
<tr>
<td>Hard rock</td>
<td>2.25</td>
<td>(1.26, 4.02)</td>
</tr>
<tr>
<td>Rap</td>
<td>1.26</td>
<td>(0.67, 2.35)</td>
</tr>
<tr>
<td>Blues</td>
<td>1.90</td>
<td>(0.70, 5.19)</td>
</tr>
<tr>
<td>Jazz</td>
<td>1.64</td>
<td>(0.74, 3.61)</td>
</tr>
<tr>
<td>Country</td>
<td>1.60</td>
<td>(0.97, 2.65)</td>
</tr>
<tr>
<td>Show tunes</td>
<td>3.12</td>
<td>(1.65, 5.89)</td>
</tr>
<tr>
<td>Easy listening</td>
<td>3.67</td>
<td>(1.78, 7.58)</td>
</tr>
<tr>
<td>Religious</td>
<td>2.19</td>
<td>(1.34, 3.56)</td>
</tr>
<tr>
<td>Classical</td>
<td>1.59</td>
<td>(0.76, 3.27)</td>
</tr>
</tbody>
</table>

An odds proportion greater than 1 denotes a shift downward in the appreciation of a given musical style from pre- to postimplant.

Since a third to a half of participants did not respond to most music types, the tables or responses were rather sparse. To increase stability in the estimation, a small constant of 0.001 was added to each cell count. This constant was chosen through an empirical sensitivity analysis in regards to effectiveness of stabilization coupled with negligible parameter influence.
Table 4  Musical Style Preference, Pre- and Post-Implantation

<table>
<thead>
<tr>
<th>Show Tunes</th>
<th>Easy Listening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difference 95% CI</td>
<td>Difference 95% CI</td>
</tr>
<tr>
<td>Pop</td>
<td>1.21 (0.70 2.10)</td>
</tr>
<tr>
<td>Rock</td>
<td>1.57 (0.99 2.47)</td>
</tr>
<tr>
<td>Hard rock</td>
<td>1.39 (0.73 2.64)</td>
</tr>
<tr>
<td>Rap</td>
<td>2.48 (1.13 5.47)</td>
</tr>
<tr>
<td>Blues</td>
<td>1.64 (0.79 3.38)</td>
</tr>
<tr>
<td>Jazz</td>
<td>1.90 (1.08 3.37)</td>
</tr>
<tr>
<td>Country</td>
<td>1.95 (1.06 3.59)</td>
</tr>
<tr>
<td>Religious</td>
<td>1.42 (0.74 2.74)</td>
</tr>
<tr>
<td>Classical</td>
<td>1.96 (1.11 3.46)</td>
</tr>
</tbody>
</table>

A difference greater than 1 denotes a proportionally greater shift downward in the appreciation of show tunes or easy listening from pre- to postimplant as compared to the downward shift in the appreciation of the various music types listed in the left column. As the difference increases, the shift in the appreciation of show tunes or easy listening becomes proportionally greater. A confidence interval that contains 1 reflects the lack of a statistically significant difference between the shifts in appreciation from pre- to postimplant.

An example of reading this table would be for rap music, the odds proportion (as defined in the previous table) for show tunes is 2.48 (1.13 to 5.47) times larger than that for rap music. That is, if for rap music, the odds of responding level J or lower postimplant is two times higher than the odds of responding level J or lower preimplant (for J = 1 [strongly dislike], 2 [dislike], 3 [like]), then for show tunes, the odds of responding level J or lower postimplant is 2*2.48 = 4.96 times higher than the odds of responding level J or lower preimplant (for J = 1 [strongly dislike], 2 [dislike], 3 [like]).

error (SE) of the obtained difference in appreciation between the two tested styles. However, jackknife SE estimates based only on those participants responding pre- and postimplant for each pair of styles were remarkably close when calculated on a style-wise basis. Thus, the jackknife SE estimates lend confidence to the accuracy of the preference change when looking at pairwise differences as well. Interestingly, "show tunes" (see Table 3) and "easy listening" (see Table 3) were the only two that showed any significantly different shifts in the proportional odds. Table 4 expresses these differences and gives an approximate 95 percent confidence interval using the jackknife SE estimates. Again, it should be noted that although only about half of the styles showed significant differences, the overall trend of the point estimates provides extra evidence that the two styles show more of a drop than the other forms.

Enjoyment of Different
Instrumental Timbres

Most normal-hearing people have personal preference for some instruments over others (e.g., may prefer a trumpet to a violin, etc.). Prior research indicates a significant difference between normal-hearing adults and implanted adults regarding appraisal of selected musical instruments (Gfeller et al., 1998a). As a result, the questionnaire included items to assess reported liking of 10 commonly heard musical instruments representing different instrumental families representing different principles of sound production and different frequency ranges. They include string family (violin and cello), woodwind family (flute, clarinet, and saxophone), brass family (trumpet and trombone), percussion (piano, pitched percussion; drum, nonpitched percussion), and organ. The latter was included because of its familiarity and common use and because it was often specifically noted in the open-ended survey of implant recipients (Gfeller, 1998).

Appraisal or degree of liking of those same 10 instruments was measured using 100-mm visual analog scales with bipolar anchors of "dislike very much" (score = 0) to "like very much" (score = 100). Respondents were asked to indicate how much they enjoyed the sound quality of each instrument that they recall having heard postimplantation. Figure 2 lists the mean score.

Figure 2  Mean appraisal scores for instrumental timbre.
Table 5  Correlation Matrix: Instrumental Timbre Appraisal × Age, Postimplant Listening Habits, Vowel Test, VMT1, VMT2, and SCT

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Age</th>
<th>Postimplant Habits</th>
<th>Vowel Test</th>
<th>VMT1</th>
<th>VMT2</th>
<th>SCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Violin</td>
<td>-.518</td>
<td>.360 *</td>
<td>.394 *</td>
<td>.401</td>
<td>.406</td>
<td>.370</td>
</tr>
<tr>
<td>Cello</td>
<td>-.590</td>
<td>.744 **</td>
<td>.620 **</td>
<td>.524</td>
<td>.591</td>
<td>.616</td>
</tr>
<tr>
<td>Flute</td>
<td>-.555</td>
<td>.306 **</td>
<td>.540 *</td>
<td>.538</td>
<td>.519</td>
<td>.313</td>
</tr>
<tr>
<td>Saxophone</td>
<td>-.457</td>
<td>.574 *</td>
<td>.508 *</td>
<td>.288</td>
<td>.330</td>
<td>.508</td>
</tr>
<tr>
<td>Trumpet</td>
<td>-.377</td>
<td>.518 *</td>
<td>.537 *</td>
<td>.235</td>
<td>.233</td>
<td>.349</td>
</tr>
<tr>
<td>Trombone</td>
<td>-.294</td>
<td>.345</td>
<td>.365</td>
<td>.593</td>
<td>.439</td>
<td>.682</td>
</tr>
<tr>
<td>Piano</td>
<td>-.355</td>
<td>.550 ***</td>
<td>.332 *</td>
<td>.178</td>
<td>.182</td>
<td>.256</td>
</tr>
<tr>
<td>Drum</td>
<td>-.371</td>
<td>.421 *</td>
<td>.135</td>
<td>.398</td>
<td>.244</td>
<td>.274</td>
</tr>
<tr>
<td>Organ</td>
<td>-.082</td>
<td>.304 *</td>
<td>.086</td>
<td>.157</td>
<td>.338</td>
<td>.118</td>
</tr>
</tbody>
</table>

* <<.05, **<.01, ***<.001.

For appraisal arranged by instrumental family groups. Although evaluations were generally in the upper half of the range, there was considerable variance among respondents and among instruments. The range of mean scores across the 12 instruments, however, is relatively narrow, indicating no obviously “better” timbres for implant recipients as a whole.

Correlations between self-reported enjoyment of the various instrumental timbres were calculated with age, length of profound deafness, age of implant use, listening habits, speech perception, and cognitive perception measures (Table 5). Those factors significantly correlated with the ratings of the greatest number of instruments include age and postimplant listening habits. The VMT, at both the one and two per second rate, correlated significantly with the ratings of violin, cello, flute, clarinet, and trombone but did not correlate with ratings of trumpet, saxophone, and piano. The VMT at the one per second rate correlated with the ratings of drums, and at the two per second rate, the VMT correlated with the ratings of organ. The SCT correlated with ratings of violin, cello, flute, saxophone, trumpet, and trombone but did not correlate with ratings of clarinet, piano, drum, and organ. Taken together, these data suggest that preimplant abilities to rapidly identify sequentially arrayed stimuli may relate to enjoyment of particular aspects of music stimuli (e.g., tone quality) postimplantation. Neither length of profound deafness nor length of implant use was significantly correlated with any of the instrument ratings. Musical training prior to deafness was significantly correlated with only two of the instrument ratings (trombone and flute). Few significant correlations (one to three instrument ratings per speech perception measure) were obtained between speech perception and timbre appraisal measures, with the exception of the vowel test, which was correlated significantly with 6 of the 10 instruments.

Environmental/Listening Circumstances That Enhance or Impede Music Listening

Sixteen specific questions provided an opportunity for the respondents to rate enjoyment associated with various musical environments or types of sound equipment on a 4-point Likert-type scale (with a score of 4 being most enjoyable). Figure 3 shows the percentage of respondents who reported having had experience listening in each of the situations, along with the mean scores for particular listening situations. Although few reported playing a musical instrument, with the exception of using direct input, the majority of implant recipients had had musical experience in most of the settings assessed. Importantly, however, the mean ratings of the musical experiences suggest that they were not highly enjoyable.

The listening environments included in the questionnaire are complex listening situations that often require the listener to organize and comprehend a mixture of music and speech, to integrate the signal with prior knowledge about the music, or to extract the musical sound from background noise. Music varies considerably in its structural complexity and may be presented with or without visual cues. Therefore, we examined the extent to which satisfaction in music listening in these listening circumstances was...
correlated with age, length of profound deafness, length of implant use, musical background, listening habits, speech outcome measures, and preimplant cognitive measures. Those factors yielding the strongest correlations include age (negatively correlated with satisfaction in all 16 listening situations except one and significantly correlated for 8 of those), preimplant listening (11 of the 16 situations), and postimplant listening habits (13 of the 16 listening situations). Listening to music while in the car, either from the radio or from a cassette recording, is significantly correlated with a number of speech measures (Table 6). The VMT (regardless of stimulus presentation rate) correlated significantly and positively with ratings of enjoyment of the radio or recorded music played in the car, recorded music through speakers, singing, indoor and outdoor concerts, and music on TV. The SCT correlated with ratings of enjoyment in those same settings, except outdoor concerts (only approached significance). The SCT and the VMT (one per second rate) also correlated significantly with enjoying music over public address systems in restaurants and stores. Taken together, these correlations suggest that
those implant recipients who are better at identifying rapidly changing and sequentially arrayed stimuli find musical experiences under less than ideal conditions to be more enjoyable than implant recipients who do not manifest those cognitive and attentional skills. No significant correlations were found for length of profound deafness or length of implant use.

In addition to using a Likert-type-scale, we devised a list of 20 factors that implant recipients had reported as affecting the quality of their musical experiences. Some factors are related to nonmusical cues and past listening experiences (e.g., watching the performer, length of cochlear implant use); other factors were related to the properties of the music itself (e.g., structural simplicity, volume, etc.). Still other factors were related to the acoustic properties of the listening environment, whether it was ambient sound or through headphones (e.g., quiet environment, direct input, etc.). In response to each item, the respondent was to mark a “+” if that factor enhanced music listening, a “0” next to items that had no perceptible influence, and a “−” next to factors that seemed to impede musical enjoyment. As Figure 4 illustrates, certain factors, such as prior familiarity with the music or a quiet listening environment, are especially helpful in an enjoyable music listening experience. A large proportion of respondents indicated that loud volume or a noisy room detracts from listening enjoyment. Figure 4 provides the relative ratings of each item for positive or negative impact. No specific implant device was identified with particularly positive or negative music listening experiences on any of the factors evaluated in this study.

Discussion

A wide range of musical involvement and enjoyment on the part of adult cochlear implant recipients was reported. Because musical tastes

<table>
<thead>
<tr>
<th>Organ</th>
<th>Choir</th>
<th>Radio/Car</th>
<th>Radio/Direct Input</th>
<th>Radio/Work or Home</th>
<th>Live Concert Indoors</th>
<th>Live Concert Outdoor</th>
<th>Background Music/TV</th>
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<tbody>
<tr>
<td>r</td>
<td>p</td>
<td>n</td>
<td>r</td>
<td>p</td>
<td>n</td>
<td>r</td>
<td>p</td>
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<td>.121</td>
<td>61</td>
<td>-.158</td>
<td>64</td>
<td>-.118</td>
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<td>*</td>
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<td>.219</td>
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<td>Secondary and university</td>
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<td>.133</td>
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<td>.111</td>
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<td>.321</td>
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<td>59</td>
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<td>.299</td>
<td>*</td>
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</table>

* <.05, **<.001, ***<.0001.

r = correlation, p = p value, n = number of participants responding.
and involvement vary considerably within the normal-hearing population, as well as among persons with assistive hearing devices, it is important to consider postimplantation responses in contrast to reports of musical lives prior to hearing loss in order to more clearly determine the impact of the implant on music involvement. Not surprisingly, global self-assessment of music listening prior to deafness and postimplantation indicates that implant recipients generally report spending less time listening to music after implantation than prior to sustaining a profound hearing loss.

The extent to which music listening is satisfactory after implantation varies considerably among recipients. Approximately one-quarter of the sample indicated little satisfaction in music listening prior to or after implantation. However, approximately two-thirds of the sample were optimistic because (a) music was becoming more pleasant over time, (b) some music was better than none, or (c) music was actually considered to be more pleasant than what was recalled prior to the hearing loss. Several persons who reported greater enjoyment of music postimplantation had lost their hearing over a lengthy time period; in their last few years of hearing aid use, hearing aids did little more than transmit basic rhythmic pulses. Consequently, the implants, although far from providing faithful representation of music, were reported to offer more input with regard to pitch-based and timbral percepts than did traditional hearing aids. Thus, a number of implant recipients indicated that hearing music through an implant, although not perfect, was preferable to not hearing music at all.

If ratings of instruments reflect something about the benefit one receives from an implant, the correlates of instrument ratings provide an interesting picture of predictors of one dimension of implant benefit. Although it is not surprising
that appraisal of musical instruments correlated with age and postimplant listening habits, it is somewhat surprising that duration of profound deafness and duration of implant use were not predictive of ratings of instruments. Both of those factors have been related to other indices of implant benefit (Tyler and Summerfield, 1996). The fact that the preimplant cognitive measures correlated with the ratings of musical instruments is conceptually consistent with the recent work by Gfeller et al (1998a), where those preimplant cognitive measures predicted the ability to recognize timbral differences in instruments. The present data and the earlier work strongly implicate some cognitive abilities in determining a range of implant benefits well beyond speech perception. Additionally, the modest correlations between speech perception and the ratings of sound quality of instruments in the present study are also consistent with the lack of an association between accuracy in the identification of instrumental timbre and speech perception in the Gfeller et al (1998a) study. Importantly, these data do not support the idea that particular musical instruments are inherently more pleasant for implant recipients.

The possible importance of specialized cognitive abilities in the outcome of implants was also implicated in the correlations between ratings of musical stimuli in various listening environments. That is, the VMT has been shown to predict speech perception (e.g., Knutson et al, 1991) and timbral recognition (Gfeller et al, 1998a), and in the present study it predicts the appreciation of music in some very difficult listening environments. Importantly, since the

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**Figure 4** Factors that enhance or impede musical enjoyment.
VMT is not a self-report measure, the correlations between the VMT and the various indices of musical listening activity and enjoyment cannot be attributed to some shared method variance. Although the speech perception measures did not correlate well with the instrument ratings, strong correlations between speech recognition tasks and reported participation in complex music listening tasks probably reflect the role of speech perception in those activities where there is likely to be a combination of both spoken and musical information. The fact that various aspects of music listening are differentially correlated with different types of speech recognition and cognitive tests indicates that music listening may require different acoustic processing than speech and reinforces the idea that the term music reflects a wide range of acoustic sounds, listening situations, and social circumstances. In short, one global indicator for music perception or enjoyment does not adequately reflect the diverse universe of musical sounds and listening experiences any more than one test could appropriately reflect all aspects of spoken communication.

Not surprisingly, general enjoyment of music was positively correlated with time spent in listening to music postimplantation. However, it is not clear whether more practice or exposure to music enhances music listening over time or whether those who receive a relatively pleasant signal soon after hook-up are more likely to spend time in music listening. Further testing is required to determine the effects of listening experience. It is noteworthy that age was negatively correlated with almost every indicator of musical enjoyment, including general satisfaction. Perhaps the changes in perceptual processing associated with aging have a negative impact on an older implant recipient's ability to use complex sequential information such as music. It is also noteworthy that there are no obvious differences among the responses of implant recipients who use devices based on very different coding strategies.

According to these data, there are no particular styles or genre of music that implanted adults report as preferable to others as a function of the implant. Average scores for each musical style showed some decline in appraisal from recollection of enjoyment prior to deafness compared with present enjoyment postimplantation. However, those declines are relatively modest. Only in the case of two genres, "easy listening" and "show tunes," do statistical analyses indicate a significant drop in reported enjoyment of that style postimplantation. The structural characteristics of the easy listening genre may in part explain this decline. Although many implant recipients find that a clear and prominent beat facilitates understanding, many "easy listening" selections do not include a clear and obvious rhythmic pulse. In addition, some implant recipients find it helpful to follow along with familiar lyrics while listening. Many "easy listening" selections include only instrumental music, such as an orchestra of string instruments. Often, "easy listening" music is played over public address systems at places of business. This is a listening situation that many of these respondents characterized as less than ideal. Finally, perhaps the term "easy listening" seems ironic to implant recipients, who find it difficult to follow along with music (see Fig. 1). The genre of "show tunes" often includes lyrics, which may or may not be intelligible to implant recipients. However, there is often a full orchestra and sometimes a chorus that accompanies the solo voice. Perhaps this very complex multitude of instruments and voices playing many notes at one time results in a signal that is too complex for implant recipients using the present generation of devices.

STUDY 2

The questionnaire data from study 1 indicate that implant recipients can describe a range of musical experiences subsequent to their receipt of a cochlear implant. Moreover, the data indicate that there may be considerable variability among implant recipients with respect to the degree to which they find musical experiences enjoyable. Although the questionnaire data provide a reliable and efficient means of collecting information from implant recipients, the results reflect the participants' integration of the sum total of their listening experiences over a long period of time. To determine whether musical listening experiences varied as a function of implant use, a daily diary was used to determine the number of hours in a day that implant recipients actually devoted to musical listening.

Method

Participants

Sixty-seven postlingually deafened adult implant users drawn from the same population as study 1 participated. Fifty-two of the implant recipients from study 1 also participated in
study 2. Because the diary protocol was introduced after many implant recipients had had years of experience with their cochlear implants, the sample of 67 participants included Ineraid and Nucleus users with up to 7 years of experience with an implant, as well as Clarion users who had only 1 year of implant use.

**Diary Forms.** The diary forms included true-false items with respect to engaging in various hearing activities and items that permitted the respondents to indicate the number of hours during 1 day devoted to a number of specific listening contexts. For the purposes of the present study, five items related specifically to musical activities were analyzed.

**Procedure**

Approximately 2 to 3 weeks prior to annual follow-up visits to the Iowa Cochlear Implant Clinical Research Center, research participants were mailed a packet of daily diary forms and seven self-addressed postage-paid return envelopes. Participants were instructed to complete one diary form each day for 7 consecutive days. To ensure that participants actually completed the diaries on a daily schedule, they were told to mail a diary form as soon as it was completed. Research assistants could then use postmarks to assess compliance with the daily protocol.

**Results**

To determine whether time engaged in musical activities was affected by the duration of implant use, the mean number of hours per day devoted to the use of radio, recorded music, concert attendance, and the playing of musical instruments was contrasted between three groups of participants. Long-term users (n = 15) had 60 months or more of implant experience, midterm users (n = 21) had at least 36 months of implant experience but less than 60 months, and short-term users (n = 31) had 24 months or less experience with the device. All of the long-term users were recipients of the Ineraid or Nucleus devices, and all of the short-term users were recipients of the Clarion device.

Figure 5 shows the mean number of hours of each of the various musical activities engaged in by the three groups. Although the overall means suggest that the short-term users engaged in somewhat more daily musical participation, the variability within groups was as great as the variability across groups, and group differences did not meet contemporary standards of statistical significance.

As an alternative analytic strategy, a within-subjects analysis of musical participation was completed with a subgroup of participants (n = 29) who completed diaries at annual intervals across 3 years. Much like the between-subjects analyses, the data did not suggest that musical participation changed appreciably as a function of implant experience. Importantly, however, based on both the within- and between-subjects analyses, the diary data do indicate that some cochlear implant recipients may devote considerable time to musical listening. The overall mean scores, however, did not adequately reflect the fact that some implant recipients actively participated in a large amount of musical activities and others did not.

Although analyses of speech perception outcome data do not suggest that there are significant differences between the audiologic outcomes of the Ineraid and Nucleus implants, design differences between the two devices suggest that there could be differences in responding to musical stimuli. Additionally, because the Clarion device uses yet another processing strategy that could affect musical listening, the percentage of recipients of each device who participated in various musical listening activities was assessed. For this analysis, the percentage of recipients with each device who engaged in musical activity at follow-ups from 12 months to 120 months is shown in Figure 6. To complete this analysis, there had to be at least six participants within the device group who provided data. Clearly, the long-term data are primarily based on Ineraid and Nucleus
and the playing of musical instruments, a majority of implant users actively engage in some musical listening.

Discussion

The daily diaries of study 2 provide a systematic replication and extension of the results of study 1. Most importantly, for both long- and short-term implant users, participation in a broad range of musical activities was reflected in the daily diaries. There was, however, considerable variability among recipients with respect to the type and amount of musical participation, regardless of the implant device used and the duration of implant experience. The lack of systematic change in diary reports of music participation as a function of implant experience in both between- and within-subject analyses is somewhat surprising. Although the detection of change could be compromised by the variance, it may be that implant recipients are not actively pursuing musical listening opportunities and testing their limits. Thus, although the diary data, uncompromised by long-term retrospective recall, indicate that musical listening is one important aspect of implant outcome that is worthy of consideration in the evaluation of the current generation of cochlear implants, the data do not suggest that musical listening has been fully explored by implant recipients.

GENERAL DISCUSSION

The data from both study 1 and study 2 indicate that musical enjoyment varies not only from one recipient to the next but that there are often intraindividual differences that occur depending on factors such as the listening situation (e.g., quiet room, good sound equipment, prior familiarity with the music being heard) or structural features of the music (e.g., a clear rhythmic beat). Therefore, studies regarding perception and enjoyment of music by implant recipients need to take into account the wide range of structural features and factors that have an impact on music satisfaction when evaluating success of the implant in music perception and enjoyment. Furthermore, it appears that most implant recipients can enhance their music enjoyment to some extent by controlling environmental conditions. Implant recipients may also take initiative in following visual cues, such as following the lyrics of a song, in order to more easily understand the signal. These
practical listening strategies can reduce the impact of the limitations of the present generation of devices.

For persons who once enjoyed music but who find the present signal to be unacceptable, music can be a frustrating experience. "I hear it as tinny," writes one person. "I love music and miss it very much. Most music is not very pleasant to listen to. It is all pretty confusing," responded another. Yet another recipient writes, "I think that listening to music is a wonderful pastime, giving hours of pleasure and enjoyment. I wish I could really enjoy it again..." Still another implant recipient describes music as "just noise."

However, a perusal of open-ended comments by implanted recipients emphasizes the sociocultural component of music listening, that is, musical enjoyment is influenced by more than the acoustic signal. A number of implant recipients describe ways in which music listening has enhanced the quality of their life with regard to particular life events (e.g., music as a part of funerals or holiday celebrations) or social structures. One recipient states that he attends all concerts for his area concert association: "I get very little out of them. It is still better than sitting at home doing nothing." Another writes, "Getting music back [that is postimplantation] filled in holes for me. It's the little stuff, even the music they play on the Cable Weather Channel, the music that accompanies skaters in competitions—with the cochlear implant, I realize how much more interesting it is to watch when I can hear the music and relate it to their choreography... I think that those of us who were intimately connected to music before our hearing losses notice the little ways the music is part of the warp and woof of life, and relish our recovery of something priceless." Although these implant users acknowledge openly that music does not sound "normal" or completely satisfactory, there are some users who emphasize the significant role that having "some music" can play in helping them to feel connected to the hearing world. For example, one person writes, "This last Christmas, on PBS, I listened to the Moorhead College Choir of Atlanta. The singing was great. It was captioned, which helped me with the words. I really enjoyed the presentation, so much so that tears literally streamed down my cheeks the whole time. No, music is not the same as before, but it's good. I can experience it, feel it." Another person wrote about the important expressive role that music played at the time of his father's funeral: "Taps from the military rites [played at the funeral] played over and over in my mind, which is OK—that is a part of grieving. [After the funeral] I put in a CD called Classical Jukebox, curled up on the couch with a warm blanket, and listened to that music in a quiet house for hours... Music opens up ways to enjoy and cope with life." These comments emphasize the importance of considering the sociocultural and acoustic aspects of the listening experience when considering music perception and enjoyment via the cochlear implant.

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