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The Effects of Familiarity and Complexity on Appraisal of Complex Songs by Cochlear Implant Recipients and Normal Hearing Adults

Kate Gfeller, PhD, RMT

F. Wendell Miller Distinguished Professor
The University of Iowa and The University of Iowa Hospitals and Clinics

Aaron Christ, MS

The University of Iowa

John Knutson, PhD

The University of Iowa and The University of Iowa Hospitals and Clinics

Shelley Witt, MA CCC-A

Maureen Mehr, BS

The University of Iowa Hospitals and Clinics

The purposes of this study were (a) to develop a test of complex song appraisal that would be suitable for use with adults who use a cochlear implant (assistive hearing device) and (b) to compare the appraisal ratings (liking) of complex songs by adults who use cochlear implants (n = 66) with a comparison group of adults with normal hearing (n = 36). The article describes the development of a computerized test for appraisal, with emphasis on its theoretical basis and the process for item selection of naturalistic stimuli. The appraisal test was administered to the 2 groups to determine the effects of prior song familiarity and subjective complexity on complex song appraisal. Comparison of the 2 groups in-

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dicates that the implant users rate 2 of 3 musical genres (country western, pop) as significantly more complex than do normal hearing adults, and give significantly less positive ratings to classical music than do normal hearing adults. Appraisal responses of implant recipients were examined in relation to hearing history, age, performance on speech perception and cognitive tests, and musical background.

The cochlear implant is a prosthetic device designed primarily to assist people who have severe to profound sensorineural deafness with verbal communication. The implant does not transmit a true replica of sound, as heard through a normal ear, but rather transmits those aspects of the sound signal considered especially salient to speech perception. (A description of the basic parts of a cochlear implant and commonly-used types of signal processing appears in the Appendix.) Research indicates that in general, the implant has been quite successful in transmitting speech sounds, with the majority of postlingually deafened implant recipients who use current-day devices achieving above 80% correct on high-context sentences in quiet listening conditions without visual cues (Wilson, 2000).

As implants have improved for transmitting speech sounds, and advanced processing strategies continue to emerge, those implant recipients for whom music was once a valued art form and social activity express the desire that they may once again appreciate music through their implants (Gfeller & Lansing, 1991; Gfeller et al., 2000; Gfeller, Woodworth, Witt, Robin, & Knutson, 1997; Stainsby, McDermott, McKay, & Clark, 1997). A recent survey of experienced adult users in our own program ($n = 63$), for example, indicates that 75% enjoyed and listened to music extensively prior to hearing loss. Unfortunately, 83% of that sample reported a decline in musical enjoyment postimplantation (Gfeller et al., 2000). These outcomes regarding impaired musical enjoyment are consistent with reports from other research centers (Dorman et al., 1990; Fujita & Ito, 1999; McDermott & McKay, 1997; Pijl & Schwartz, 1995; Schultz & Kerber, 1994).

Perception and Appraisal of Music through Cochlear Implants

With regard to perceptual accuracy, the decline in musical enjoyment is related to technical limitations of the implant in transmitting key structural features of music. Although implant recipients have similar perceptual accuracy as normal hearing adults for simple rhythms presented at a moderate tempo, they demonstrate significantly poorer accuracy for discrimination or recognition of pitch-based patterns and timbre (Fujita & Ito, 1999, Gfeller & Lansing, 1991, 1992; Gfeller et al., 1997; Gfeller, Knutson, Woodworth, Witt, & DeBus, 1998; Pijl, 1997; Pijl & Schwartz, 1995). For example, some implant recipients describe the notes in a familiar melody as sounding like a series of random pitches, a monotonic repetition, or as altered in contour. This problem is likely a result of poor frequency resolution provided by current-day implants (Fearn & Wolfe, 1998). While implants are more effective in transmitting spectral features than pitch, the representation of timbre is far from ideal. Implant recipients are significantly less accurate than normal hearing adults on perception (recognition) of musical instruments by sound alone (e.g., Dorman et al., 1990; Fujita & Ito, 1999; Gfeller & Lansing, 1991, 1992; Gfeller et al., 1997; Gfeller et al., 1998; Pijl, 1997; Pijl & Schwartz, 1995; Schultz & Kerber, 1994).

Although there is considerable variability among implant recipients regarding ratings of sound quality (appraisal, or liking), many implant recipients have characterized the sound quality of music through implants as scratchy, squeaky, tinny, booming, unnatural, mechanical, or noise-like (Dorman, Basham, McCandless, & Dove, 1991; Gfeller, 1998; Gfeller et al., 1998; Gfeller et al., 2000; Schultz & Kerber, 1994). Existing research indicates that implant recipients give poorer ratings to the quality of solo musical instruments than do adults with normal hearing (Gfeller & Lansing, 1991, 1992; Gfeller et al., 1997; Gfeller et al., 1998). Such an aversive rating of music is unfortunate, given the fact that music is such a pervasive acoustical event in everyday life. With implant recipients virtually certain to be exposed to musical sounds regularly, and most likely to be interested in active listening, the extent to which implants transmit musical sounds effectively is of considerable pragmatic interest.

The previous paragraphs summarize the primary findings of extant research regarding music perception and appreciation of cochlear implant recipients. Most of these studies examine perceptual accuracy and appraisal of specific and isolated structural features of music (e.g., rhythm, pitch, melody, timbre of individual instruments). These studies help identify which structural elements are more and less effectively transmitted through the implant.

However, seldom do people hear isolated elements of music in everyday listening. Rather, music is experienced as complex patterns combining pitch (melody and harmony), timbre, and rhythm that cannot be represented adequately only through isolated and synthetic models (Hargreaves, 1986). Studies examining naturalistic stimuli more representative of everyday listening experiences are of practical and theoretical interest to better understand how effectively the implant transmits complex musical sounds. However, examining the response of implant recipients to naturalistic musical stimuli requires suitable measurement tools. A review of existing tests of music aptitude and appreciation, as well as measures used in audiology revealed no existing tests suitable for use with implant recipients, or for the specific research questions of this study. Therefore, the first objective of this study was to develop a test for measuring appraisal of complex, naturalistic musical stimuli of the sort heard in everyday life that would be suitable for use with adults who use cochlear implants.

As a preliminary step to instrument development, existing theories and models of music appraisal were examined for their relevance to the research questions and population of interest. Although the following theories regarding musical appraisal were developed with normal hearing individuals in mind, they provided a systematic view of the primary factors likely to be influential in musical appraisal, and thus provided a framework for test development.

Theoretical Considerations Relevant to Appraisal of Complex Musical Stimuli and Applicability to Cochlear Implant Research

Objective and Subjective Complexity in Relation to Appraisal

Because two primary functions of music in society are aesthetic enjoyment and entertainment (Merriam, 1964), the extent to which music sounds pleasant (appraisal) has been an important area of research for adults with normal hearing. Though appraisal has been explored considerably less than perceptual accuracy among implant recipients, one could argue that musical appraisal is a more stringent indicator of implant benefit than is perceptual accuracy (e.g., pitch discrimination).

An interesting relationship exists between perceptual accuracy and appraisal. On one hand, song identification or recognition is not required for appreciation. People with normal hearing acuity often enjoy music that they cannot identify by song title. Conversely, people may dislike musical selections that they can easily recognize. However, research indicates that normal hearing listeners tend to prefer music in which they can readily perceive patterns of redundancy and variation (as opposed to hearing a chaotic sequence of seemingly random sounds), but which holds enough novel information to sustain the listener's interest (Berlyne, 1971; Meyer, 1956)—that is music which has an optimal level of complexity. What is meant by complexity? Two types of complexity commonly appear in research literature regarding music appraisal: objective and subjective complexity.

Objective complexity of a given musical selection may be determined by calculating the amount of variability or uncertainty associated with a given musical event. According to information theory, this quantification is directly related to the amount of information and redundancy within the event, which is first perceived by the peripheral hearing mechanism, but then processed for form and meaning by the central nervous system. Music with considerable structural redundancy (e.g., very simple and repetitive melodic or rhythmic patterns) is more easily organized than complex patterns, and future musical events can be predicted more quickly. These patterns are processed not only as a structural entity but are also "heard" within the context of past listening experiences that have contributed to the development of neural networks and associations. That interaction between perception of the present sound and past listening experiences is an essential component of what is called subjective complexity.

According to Price (1986), subjective complexity is the "perceived complexity level or information content, which is mutable and a function of the listener and past musical experience" (p. 154). In other words, subjective complexity is the result of the interaction between the objective complexity (structural characteristics) of the stimulus and the listener's musical knowledge, prior experience with the musical style and/or idiom, and familiarity with the particular musical stimulus (Radocy & Boyle, 1988). Therefore, subjective complexity can be modified by repeated exposure, training, or practice, which can lower the perceived stimulus complexity and thus alter the affective value of the stimulus pattern (Radocy & Boyle, 1988). Thus, 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 selections (i.e., familiarity) (Berlyne, 1971; Gfeller, Asmus, & Eckert, 1991; Gfeller & Coffman, 1991; Hargreaves, 1986; Heyduk, 1975). In short, subjective complexity of the stimulus is an important factor in musical taste and enjoyment of persons with normal hearing (Cuddy & Upitis, 1992; Hargreaves, 1986; Heyduk, 1975; Radocy & Boyle, 1988).

Are the constructs of objective and subjective complexity relevant to musical listening experiences of cochlear implant recipients? The fact that implants transmit a more normal representation of rhythm than pitch or timbre has clear implications for objective complexity. Research indicates that some structural patterns considered redundant and easy to follow for normal hearing persons are not easy for many implant recipients (see Gfeller et al., 1997; Gfeller et al., 1998; Gfeller et al., 2000; Gfeller et al., 2002). For example, a prominent and redundant rhythmic pattern theoretically should make a piece of music much easier to follow than a similarly prominent and redundant melodic or timbral pattern (though it is important to acknowledge considerable variability among implant recipients in perception of pitch and melody perception). However, in situations that provide some context, objective complexity alone cannot adequately address perception and enjoyment for implant recipients. Anecdotally, implant recipients indicate that they use prior knowledge of music in order to make sense of a degraded or incomplete signal. (For example, one CI user described the process of identifying "Happy Birthday" as a combination of knowing that this song would be likely to be heard at a birthday celebration, along with careful attention to the rhythm pattern, after which she quickly searched her memory for "Happy Birthday" to see if it matched the rhythmic patterns just heard.) Thus, subjective complexity, which takes into account the interaction between perception of the present sound signal (objective complexity) and past listening experiences of the individual seems particularly important in listening tasks that are based upon real-life listening experiences.

Interactive Theories of Musical Preference

Research studies regarding musical preference of adults with normal hearing suggest factors in addition to stimulus complexity that may influence appraisal of music, and which may provide some relevant clues for understanding listening satisfaction of implant recipients (e.g., Brittin & Sheldon, 1995; Cutietta, 1992; Flowers, 1988; Hargreaves, 1986; Hoffer, 1992; Jaret, 1982; LeBlanc, 1982; LeBlanc, Colman, McCrary, Sherrill, & Malin, 1988; LeBlanc & Sherrill, 1986; McCrary, 1993; McMullen, 1980; Montgomery, 1996; Walker, 1980). One of the better-known interactive theories developed by LeBlanc (1982) describes musical preference as being influenced by (a) structural characteristics of the musical stimulus (e.g., how simple or complex the music); (b) the listening situation (e.g., quality of or fidelity in reproduction; influence of social group or authorities); (c) individual characteristics of the listener (e.g., auditory sensitivity, maturation, musical training); and (d) respondent action variables, which refer to the listener's experiences with a given song (e.g., prior familiarity with a specific song, familiarity with and existing attitude toward the general style of a specific musical selection). Such factors seem likely to influence the appraisal of music by cochlear implant recipients.

With regard to structural characteristics of music, it is important to reiterate that cochlear implants have been designed primarily to transmit speech sounds, and as noted previously, the implant is particularly poor at transmitting pitch information and the rich details of timbre so critical to music's beauty. Thus, based on the theory advanced by LeBlanc, how faithfully the implant represents various structural features of music and the combinations of those structural features is likely to have a particularly important influence on objective complexity, and the appraisal of music. Although the evidence reviewed above indicates that the rhythmic, timbral, and linguistic features in isolation are likely to be more accessible than pitch information alone, it is not clear how these findings would predict musical appraisal by implant recipients when these structural features are combined in complex "real-life" songs. It is possible that the additional information in a complex song will assist the implant recipients in making some sense of the signal. However, it is also possible that extracting the target melody line from the background sounds of an orchestral accompaniment may be too difficult a 'figure-ground' task, and that accompaniment may actually resemble background noise (a factor well documented as deleterious to speech perception; Wilson, 2000).

With regard to the listening situation, prior studies indicate that musical enjoyment through cochlear implants is highly influenced by the listening environment (Gfeller et al., 2000). Performance with the implant deteriorates in background noise or in a room with reverberation. However, access to visual cues (e.g., watching the singer's mouth) or prior knowledge regarding the music to be played (e.g., closed-set listening task) can assist in understanding the sound signal. In addition, the social circumstances surrounding the event may also influence appraisal. For example, some implant recipients report that the social aspects of attending a music concert and feeling a part of a social group can reduce the negative effects of compromised sound quality.

Individual characteristics of the listener who uses a cochlear implant (e.g., age, music listening experiences, cognitive abilities) may influence music listening. For example, past studies of implant recipients indicate that age is negatively correlated with perceptual accuracy for rhythm, pitch, pitch sequences, melody recognition, timbre recognition and appraisal, and self-reported enjoyment in music listening (see Gfeller and Lansing, 1991, 1992; Gfeller et al., 1997; Gfeller et al., 1998; Gfeller et al., 2002). Length of profound deafness was significantly negatively correlated with simple melody recognition (Gfeller et al., 2002) but not with other tasks of pitch-pattern discrimination or timbre recognition and appraisal. It is interesting to note that length of device use, which is typically an important predictor for speech perception (Tye-Murray, Tyler, Woodworth, & Gantz, 1992; Tyler & Summerfield, 1996), has not been significantly correlated with any measures of music perception or appraisal. That is, music perception and enjoyment do not improve as a result of incidental exposure to musical sounds in the general environment over time or with increased implant experience. While past studies of implant recipients have not shown significant correlations with formal musical training and perceptual accuracy or enjoyment, the amount of time spent in active, focused (as opposed to incidental exposure) listening to music postimplantation was significantly correlated with perceptual accuracy for pitch and rhythm sequences, as well as timbral recognition and self-report of musical enjoyment (see Gfeller et al., 1997; Gfeller et al., 1998; Gfeller et al., 2000). The best predictor of recognition and appraisal of isolated or simple structural elements (i.e., pitch pattern discrimination, timbre appraisal) has been cognitive tests that measure rapid identification of sequential information (see Gfeller et al., 1997; Gfeller et al., 1998; Gfeller et al., 2000). Thus, it appears that different individual characteristics are more or less implicated depending on the specific type of isolated musical structure being examined. Further research is required to determine which attributes of implant recipients are most closely related to appraisal for complex listening tasks such as musical recordings heard in everyday life.

For normal hearing people, exposure to particular styles of music (respondent action variables) within a person's social circle can influence listening tastes and music consumerism (Hoffer, 1992). According to the National Assessment of Educational Progress, adults over the age of 17 enjoy a broad range of musical styles, but prefer listening to country western, pop, and instrumental art music (e.g., classical, symphonic). Recalling the optimal complexity interactive theory described earlier, repeated exposure, which can lower the stimulus complexity, can alter the affective value of the stimulus pattern (Radocy & Boyle, 1988). Thus at least for normal hearing persons, prior and regular exposure to country, pop, or classical music is likely to have an influence upon appraisal, both for overall styles as well as prior exposure to specific musical pieces (i.e., familiarity) (Berlyne, 1971; Gfeller, Asmus, & Eckert, 1991; Gfeller & Cofffman, 1991; Hargreaves, 1986; Heyduk, 1975).

Given the very atypical manner in which cochlear implants represent musical sounds, are postlingually deafened adults who use cochlear implants able to make use of listening experiences they had prior to deafness? Anecdotally, implant recipients note that they can follow music more easily if they have knowledge of what they are hearing, and if they knew a particular selection prior to hearing loss. However, it is difficult to determine from informal comments how effectively prior familiarity functions in listening situations that provide limited contextual cues. That is, when the listener has no contextual cues about the music being heard, how well can implant recipients perceive and enjoy real-life music? To what extent do theories that explain appraisal responses in normal hearing adults apply to cochlear implant recipients, and can those theories help to predict which factors may optimize listening to complex, real-life music?

In order to examine these questions, a test was developed that addresses several factors believed to influence appraisal (liking): subjective complexity, genre, and level of prior familiarity (familiar and obscure—that is unfamiliar). It was essential to develop a test that could be readily used with two different populations: postlingually deafened adults who use cochlear implants and a comparison group of adults who have normal or near-normal hearing. For the purposes of this study, the term, "complex song" refers to cohesive units of music identified by a song title (e.g., "Hard Day's Night" by the Beatles, "Claire de Lune," by Claude Debussy). Appraisal is the term used in this study to indicate an assessment of how much the respondent liked each complex song excerpt.

Method

Development of a Complex Song Appraisal Test

The purpose of the test developed for this study was to measure appraisal (liking) and ratings of subjective complexity of familiar and obscure (unfamiliar) real-life music (complex songs). According to Boyle and Radocy (1987), whenever possible, evaluation of musical behaviors should involve response to aural musical stimuli, as opposed to relying on response to memory for prior listening experiences. This seems particularly important in research regarding appraisal by cochlear implant recipients given the marked differences between sound quality through a normal hearing mechanism and that transmitted through the device.

While the use of real aural stimuli has specific benefits, there are also challenges with regard to content (scope of coverage) and item selection when using naturalistic stimuli. Given the large and diverse universe of real-life musical sounds that exist, how does one select a sample of items that can be administered within a reasonable amount of testing time, while being adequately representative of real-life complex songs? The first decision with regard to test content was to determine those musical styles that are most commonly heard by the population from which the implant recipients are drawn.

Test Content: Scope of Coverage

The first criterion for scope of coverage was music representative of "real-life" listening experiences that would also be suitable for the target population to be tested. As noted previously, pop, country western, and classical music are the three musical genres most enjoyed by the largest proportion of adult listeners in the United States (Hoffer, 1992). Furthermore, these styles were identified as those most commonly preferred by implant recipients enrolled in our clinical research center (Gfeller et al., 2000). Pop and country western music are accessible to people of all socioeconomic classes, and are commonly heard and thus important forms of listening activity to study (Konecni, 1988). Classical music contains structural forms that differ considerably from pop and country western music, and includes a large body of work that has no lyrics (linguistic component). Based on these facts, the scope of test items was limited to these three musical styles, commonly heard in everyday experiences, which also offer an interesting range of structural features relevant to processing characteristics of cochlear implant.

Even after limiting test items to these three genre, there are still thousands of possible items for each genre from which to choose. Where does one begin in selecting specific items? Item selection was guided, in part, by optimal complexity theory (Berlyne, 1971; Hargreaves, 1986) and, in part, by respondent action variables noted in LeBlanc's interactive theory (1982) of musical preference. These theories emphasize the normal listener's experiences with a given song or musical style in appraisal (e.g., prior familiarity with a given song or musical style). Therefore, the second criterion for scope of coverage was familiarity—that is, specific items likely to be familiar to large numbers of listeners within U.S. culture. Boyle and Radocy (1987) emphasize that tests should provide a balanced sample of behaviors relevant to the test's function (content validity). Therefore, systematic methods for item selection within each genre, taking into account familiarity, were developed and are described below.

In order to select a valid and balanced sample of items truly representative of each genre, it was first necessary to formulate operational definitions for the three genre to be included. The genre, "pop (popular) music" is difficult to define from the standpoint of discrete structural characteristics (harmonic, melodic, rhythmic qualities) or lyrical themes, because divergent styles or "crossover" categories have emerged over time (Pembrook, 1990; Tudor, 1983). Popular music is available to the masses through records and radios, and is in a state of constant evolution (Tudor, 1983). According to the *New Grove Dictionary of Music and Musicians* (Lamb & Hamm, 1986), "popular music" is a "term referring both to the body of music most widely played on radio, juke-boxes and recordings and to the style of this music" (p. 111), and is readily comprehended and appreciated by a large proportion of the populace. Popular selections are typically of modest length, with prominent melodic lines sung by a vocal soloist or small ensemble, and generally a simple harmonic accompaniment.

Given the divergent styles found within popular music, structural characteristics (e.g., rhythmic, melodic elements) are not particularly useful criteria for categorizing this genre, while industry categories (Rothenbuhler, 1996) appeared to have greater utility. Therefore, the operational definition of pop music for this study was based on industry classifications—that is, music heard on radio stations that play predominately Top 40 hits (Lamb & Hamm, 1986; Pembrook, 1990; Rothenbuhler, 1996; Tudor, 1983) of a time period.

According to the *Grove Music: New Grove Dictionary of Music & Musicians,* country western, also known as country music, is a popular music style with origins in country dance tunes and ballads of Anglo-Saxon and Celtic origins 19th-century popular songs, black-American blues and gospel songs, and sacred numbers from religious revivals. It has evolved from a folk-derived art form, performed mostly by rural amateurs, into a complex multimillion dollar industry. Country songs often focus upon stories of real life—love, family, work, heartache, memories, and so on (Whitburn, 1994). Therefore, the lyrics are often a key aspect of this musical genre. Although country music has in recent years become more commonly played on pop stations, for purposes of test development, county western songs were selected from among those specifically listed in media charts for country western music.

While pop and country western genre are characterized by rapid changes in styles and popularity of particular performers and songs, stylistic structures in classical music tend to endure over many years. The term, 'classical music,' sometimes refers to a style of western European music probably best represented by the compositions of Haydn and Mozart. In common parlance, however, the term 'classical music' is often used in reference to many centuries of serious art music, which can be categorized into broad styles that have distinct structural features (i.e., Baroque music, Classical music, Romantic music, and 20th century music). Many of the most familiar classical selections are presented by solo, small or large ensembles of musical instruments; therefore, many selections have no vocalist and no linguistic content. Although there exists a continuum of simple to complex compositions within all three genre, in general, classical selections tend to have more complex melodic, rhythmic, and harmonic structures than those found in typical pop and country favorites.

Developing a Pool of Items for Each Genre

It was essential to select a body of musical selections consistent with the definitions for each of the genres, and which could also facilitate the empirical testing of whether prior familiarity influences appraisal of normal hearing and implanted adults. The following resources were used for identifying familiar items: *Billboard Book of Top 40 Hits, 1955 to Present* (Whitburn, 1983, 1987); *Top Country Singles 1944–1993* by Joel Whitburn (1994); the *Schwann Catalog*, which lists number of recordings of specific classical selections. In addition, lists of familiar classical items were provided by three university professors of music education who have extensive knowledge of those classical selections likely to be included often in music instruction for children and adolescents.

The following resources were utilized to identify obscure items representative of the three genres: for pop, Bubbling *Under the Top 100, 1959–1981* (Whitburn, 1982), which is a compilation of pop-style compositions that did not achieve large-scale popularity and familiarity; for country, lists of obscure country items compiled by three disc jockeys for country western radio stations; for classical, lists of obscure classical items (defined as likely to be known only by music historians with post-doctoral education) compiled by a professional music librarian and two professors of music history and literature.

In the development of an item pool for familiar pop and country items, it is important to take into account that the implant recipients who would be tested include persons from more than a 55-year age range. Because the pop and country music industry changes rapidly with different generations (Lamb & Hamm, 1986; Tudor 1983), it is likely, therefore, that different age groups may be most familiar with different eras of pop and country music, particularly because some studies indicate that people tend to most enjoy music popular during their teenage and early adult years (Gibbons, 1977). Therefore, for these two genres, the item pool included a stratified sampling of items representing a sequence of 8-year time periods beginning in 1955 (the time period that acts as a watershed year in the popular music industry, Lamb & Hamm,

1986) and ending in 1986 (the time when the youngest of our implant recipients was in early adulthood and still had hearing).

A stratified sampling of familiar and obscure classical music was conducted using categories of Baroque, Classical, Romantic, and 20th century styles. The list of classical items was categorized by style and also by performer characteristics (e.g., solo instrument, small ensemble, large ensemble) for final item selection. The following section describes how the pool of possible items was further narrowed.

Selecting Final Test Items from the Pool of Possible Items

Pop and country western genres. Even after selecting items for familiarity and obscurity, there remained thousands of possible items. Therefore, a systematic selection process was used to select those items that best represented highly familiar and highly obscure items. Those selections with the greatest media exposure, and presumably greatest general familiarity, were determined by reviewing specific *Billboard* listings (*The Billboard Book of Top 40 Hits 1955 to Present* and *Top Country Singles 1944–1993*) for the following: (a) the number of weeks a given song held the Number 1 spot, (b) the number of weeks the song was in the Top 10 charts, and (c) the ranking of prominence for each recording artist.

Each song title was assigned a sum score for these categories. In order to reduce the number of structural variables that might contribute to appraisal ratings by implant recipients, pop and country song selections that were instrumental only were eliminated, because instrumental-only items are relatively rare within the most familiar songs of those genres. In addition, selections by female vocalists were omitted because vocal selections by male vocalists make up the greatest proportion of popular songs from 1955 to 1986. The selection of only male solos helped to reduce the number of variables extraneous to the research hypotheses in question.

This process resulted in a list of 222 song titles with the respective recording artist for pop and also for country representing the 32 highest ranking vocal selections for each 8-year period between 1955 and 1986. In order to narrow the listing further to produce a test of reasonable length for administration, a listing of all 222 song titles (for pop and also for country) along with the recording artists was submitted to one of two panels: three university professors who do research in the area of music and mass media or popular music, and three disc jockeys from large country stations. Those experts were asked to validate for each song whether or not they considered it to be representative of the general category "pop" or country western music and also to rate each song (scale of 1 to 5) and recording artist for familiarity to the general public. All song titles and artists validated by genre type were then rated by an independent sample of 25 nonmusicians for familiarity. The final familiar items for each 8-year era were those that received the highest rankings by both the experts and nonmusicians.

In addition to selecting items having extensive media exposure and popularity, additional obscure items were included in the test that represented the styles of pop or country music, but that had not achieved public familiarity or prominence. These items were included to facilitate testing of the hypothesis of whether implant recipients are influenced by prior familiarity. The notion of obscure, nonfamiliar pop tunes seems a bit of a contradiction, since by definition, pop music is that music which has received public exposure on Top 40 stations. However, as noted previously, pop music also represents a genre of music played on particular types of media outlets, and not all popular music has achieved equal public recognition. The following criteria were used for selection of nonfamiliar songs: (a) (for pop) their appearance in the text, *Bubbling Under the Top 100 1959–1981*; (b) verification of the song's style by experts on popular music; and (c) low mean familiarity ratings by a panel of experts, and a sample of normally hearing nonmusicians.

Classical genre. The selection of most familiar classical items was developed by quantifying the exposure of specific compositions. This was accomplished by finding the most commonly recorded songs over a decade from the *Schwann Catalog*, by obtaining familiarity ratings of normal hearing nonmusicians, and by gathering familiarity ratings from a panel of three experts (university professors of music education) regarding those pieces most commonly taught in school music classes. In order to reduce influential structural variables, only instrumental items were utilized in the final pool of classical selections. Obscurity of each nonfamiliar item was validated by having a group of nonmusicians rate each item for familiarity. The final selection process included a balanced representation of solos, small ensembles, and large ensembles, with familiar and obscure items for the following styles: Baroque, Classical, Romantic, and 20th century.

Test Format and Protocol

Song appraisal. In order to reflect optimal complexity theory, which reflects in part the theoretical foundation for this study, appraisal consisted of two factors: (a) how much the individual liked the sound, and (b) how complex the item sounded, that is, how difficult the selection was to follow and understand. A review of extant studies in musical preference reveals common usage of surveys, Likert-type scales, semantic-differential scales, paired-comparisons, and behavioral observations (amount of listening behavior) for measuring musical preference or liking (Boyle & Radocy, 1987; Cutietta, 1992; Radocy & Boyle, 1988). Numerous studies of musical preference have been conducted using each of these paradigms. Because there are a variety of practicable and methodological drawbacks to each method, there is currently no clear methodological standard. For example, behavioral responses have been shown to have little relationship with verbally expressed preferences (Cutietta, 1992). Surveys of style preferences have been criticized for fostering responses in which the participant attempts to please or impress the test administrator (Radocy & Boyle, 1988). Paired-comparisons, when the test includes numerous stimulus items that are more than a second or two in length, result in extremely lengthy testing sessions. The Likert-type scale, along with the semantic-differential, requires categorical responses, which cannot assume equal interval size from one category to the next. Some have argued that using categorical measures is not as appropriate when gathering affective judgments to stimuli such as music as is magnitude estimation determined through a continuous scale (Koh, 1965). In addition, some statisticians assert that categorical responses are more suitably analyzed using nonparametric statistics, though there is controversy regarding this issue (Daniel, 1987; Popham and Sirontnik, 1973). The visual analog scale has received considerable support for measuring affective responses among many populations (Gfeller, Logan, & Walker, 1990) and provides a continuous measure appropriate for analysis with parametric statistics, which, when assumptions can be met, provides a more powerful analysis (Daniel, 1987).

Many studies have linked aesthetic judgment with the theories of optimal complexity (Berlyne, 1971; McMullen, 1980; Radocy & Boyle, 1988; Walker, 1980). For that reason, subjective complexity was measured along with appraisal. In studies that use more synthetic stimuli, it is reasonable to mathematically model the structural (objective) complexity of the object of aesthetic judgment. But even with modeled indices of complexity, different individuals will, in reality, perceive the same work as more or less complex based on past musical experiences, which can assist an individual in organizing the musical information more or less successfully. Therefore, subjective complexity, as rated by each individual was utilized as a dependent variable for this study. In order to measure liking and complexity, two visual analog scales (100 mm) were used, one with bipolar adjectives of 'like-dislike (like = 100, dislike = 0),' and the other with bipolar adjectives of 'simple-complex (complex = 100, simple = 0).'

Sound stimuli. The sound stimuli and response tasks were presented using a Mac computer with external speakers and a touch screen for responding. The Complex Song Appraisal Test included five practice items and 36 different items (12 country western, 12 pop, 12 classical), as well as 9 items repeated in order to obtain indices of internal consistency (total of 45 items). All test stimuli were excerpts (12–17 seconds) of the main themes of recordings heard in "real-life" that include various combinations of melody (sequential pitch patterns), harmony (simultaneous presentation of different pitches), rhythm, and timbre (tone quality). The items represented a continuum of vertical (harmonic) complexity, with some examples using solo instruments or vocalists, while others include complex combinations (blends) of instruments and/or voices. These complex songs reflect to considerable extent the sorts of musical stimuli heard in everyday life. Each item was then excerpted and encoded by AIFF with compression using SoundEdit 16 software (44 kHz sampling rate and 16 bits sampling size). The items were placed onto a computerized sound file for integration in a computerized testing format so that the items could be presented multiple times and in random order. Because these items are brief excerpts of longer musical selections, and because these data are being used for research (with no profit from or marketing of the test instrument), this use of recorded music falls within guidelines for use per copyright laws. In order to ensure reasonable length of administration, clarity of instructions, and appropriate response modes, pilot studies were conducted with normally hearing adults and cochlear implant recipients.

Participants

Participants included 36 adults with normal or near normal hearing (NH) and 66 postlingually deafened adults who were experienced cochlear implant users (CI). The comparison group of adults with normal hearing was recruited through newspaper ads and bulletins posted at a center for retired persons. The NH group included 29 females and 7 males, who ranged in age from 18 to 72 years of age (M = 36.28, SD = 14.41). Because only one participant in the implanted group was a professional musician, music majors and professional musicians were excluded from the comparison group. Hearing sensitivity was important to account for the ability to adequately hear and appraise music. As hearing loss is commonly associated with aging (mild losses often occur even as early as age 50), but it was desirable to include older adults in the comparison group, the following criteria were chosen to represent normal or near normal hearing adequate for the response task: (a) three-frequency pure tone average (calculate from thresholds obtained at 500, 1000, and 2000 Hz) less than or equal to 20 dB HL in at least one ear; (b) no threshold worse than 30 dB HL at 500, 1000, and 2000 Hz bilaterally; and (c) no prior or current hearing aid use. Persons who did not meet these criteria were excluded from participation.

The CI group included 30 male and 36 female implant recipients ranging in age from 24 to 81.8 years (M = 56.22, SD = 14.94) with less than one year to 58 years (M = 13.96, SD = 13.57) of profound deafness prior to implantation. Only one of the participants (Med-El device) was a professional musician, as determined through the *Iowa Music Background Questionnaire* (Gfeller et al., 2000). [Note: Because prior research (Gfeller et al., 1997; Gfeller et al., 1998; Gfeller et al., 2000; Gfeller et al., 2001) indicates that music training prior to implantation is not highly correlated with perceptual accuracy or appraisal for music, this individual was included in the group data. However, her results are addressed individually in the discussion section.] Most of the implant recipients described themselves as having been informal music listeners prior to deafness.

All implant recipients had at least 12 months experience (M = 65.47 months, SD = 44.06 months) with their implant prior to testing. The implant recipients used one of the following device types in combination with speech processing strategies: Clarion, $n = 23$ (CIS processing strategy); Nucleus CI22, $n = 8$ (1 MPeak and 7 SPEAK processing strategies); Nucleus CI24M, $n = 21$ (9 ACE and 12 SPEAK processing strategies); Med-El processor with an Ineraid device, $n = 12$ (CIS); or Ineraid, $n = 2$ (analog processing strategies). All of the aforementioned devices use a digital (pulsatile) signal that presents specific features of the signal, except the Ineraid, which uses an analog signal (the entire wave form is compressed and transmitted to an array of frequency filter banks). A brief description of the various coding strategies appears in the Appendix.

Test Administration: Complex Song Appraisal Test

The test was administered in a sound-treated room via an Apple hard drive computer (model M3409) and Yamaha external speakers (model YST-M15). Participant responded using a Sony touch screen monitor (model CPD-2000SF). The test stimuli were transmitted through the speech processor, which reflects to a considerable extent everyday listening experiences in quiet. The sound level was averaged at 70 dB SPL. However, implant recipients were permitted to adjust the volume control on their processor to a comfortable level of loudness.

After initial instructions on the computer screen, the participant viewed prompts on the computer screen to "listen" while each song item was played via external speakers. After each item was completed, a screen appeared with two visual analog scales (100 mm each) with bi-polar adjectives of 'like-dislike' and 'simple-complex.' The participants registered their responses by touching that point on the two visual analog scales that represented their opinion. No information was provided at any point during testing regarding the song title or genre of each item. This was to encourage rating of the actual stimuli heard through the implant, and to discourage ratings based on possible preconceptions about or past experiences with various artists, styles or songs. The response was automatically saved to a computer file for later analyses.

Determining Prior Song Familiarity

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 this task, familiarity (prior exposure) was considered a factor likely to influence appraisal.

Therefore, after testing was completed, participants completed the Alphabetized List of Song Titles (ALST). The ALST is an alphabetized list of 106 well known songs that included the names of the 36 complex song titles from the test. They were asked to place a check mark next to each song title that they recalled from the time prior to deafness (or prior to testing time, in the case of normal hearing adults). This list, which determined familiarity prior to deafness, provided a means for examining the role of individual familiarity in the appraisal response.

Correlational Analyses

In order to examine the influence of individual differences among the implant recipients on complex song appraisal, the dependent measures of liking and subjective complexity were correlated with measures of cognitive functioning, speech perception, hearing history, musical background, and other demographic variables. These measures are described below.

Cognitive Tests Measuring Sequential Processing

The Visual Monitoring Task (*VMT*) (Knutson et al., 1991) is a test of attention, reaction time, continuous performance, and working memory, in which participants observe a computer monitor as numbers are displayed at either a one per second rate (*VMT1*) or a one per two second rate (*VMT2*). As noted in prior studies, the *VMT* has been a strong predictor of implant recipient success in both speech recognition and music perception and appraisal tasks regardless of the implant design used Gfeller et al., 1998; Knutson et al., 1991).

The Sequence Completion Test (*SCT*) based on the work of Simon and Kotovsky (1963) required completion of a sequence of letters. The scores reflect the number of sequences correctly identified in a fixed time period. Only moderately correlated with the VMT, this test of sequence identification has also been shown to predict audiological implant benefit (Knutson et al., 1991).

Speech Perception Measures and Demographic Data Regarding Hearing History

The following measures of speech recognition were correlated with outcomes of appraisal complexity: *Iowa Medial Consonant Test* (Tyler, Preece, & Tye-Murray, 1986), and 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*).[1]

Demographic Variables

Demographic variables regarding hearing history of implant recipients examined included age at the time of testing, length of profound deafness prior to implantation, and months of implant use. Demographic data regarding musical background of implant recipients were gathered using the *Iowa Musical Background Questionnaire,* which is described in considerable detail in Gfeller et al. (2000). In general, the questionnaire provides four separate measures regarding musical background: (a) self-report of the amount of time spent in listening to music and extent of listening enjoyment prior to hearing loss, (b) self-report of the amount of time spent in listening to music and extent of listening enjoyment following implantation, (c) the amount of music education (general music classes, participation in lessons, ensembles, etc.) in elementary school, and (d) amount of formal music education in high school, college, or as an adult (e.g., lessons, enrollment in music classes, participation in ensembles). These variables were correlated with the dependent measures of liking and complexity.

Results

Although test-retest is a common method for establishing test reliability, according to Cutietta (1992), it is not recommended for attitude measurement given the ambiguities inherent in attitude. Rather, a measure of internal consistency such as the Kuder-Richardson is preferred. While coefficients of .70 and above are preferred, lower coefficients are sometimes tolerated. Internal consistency for the test (as determined using the nine repeated items) was $\alpha = .75$.

Group Differences

Prior Song Familiarity

Results from the ALST indicated that participants from the normal hearing group (NH) were familiar with a significantly greater number of the items ($p < .0001$) in the test than the adults with the implants (CI). This is not particularly surprising, given that the implanted adults had been deafened for as many as 58 years (mean length of profound deafness = 13.96 years), and consequently would have had less opportunity for exposure to different songs over time. However, the patterns for familiarity across genre were

TABLE 1

Mean Scores for Appraisal (Liking)

	Factor				
	Classical	Country	Pop	Familiar	Obscure
Normal hearing ($n = 36$)	$M = 69.02$; $SD = 24.61$	$M = 46.05$; $SD = 28.68$	$M = 58.70$; $SD = 28.36$	$M = 62.55$; $SD = 10.12$	$M = 50.30$; $SD = 14.31$
Implant recipients ($n = 66$)	$M = 50.34$; $SD = 25.99$	$M = 54.15$; $SD = 23.79$	$M = 54.05$; $SD = 25.23$	$M = 54.05$; $SD = 7.64$	$M = 50.09$; $SD = 6.44$

similar between the two groups: Both groups were significantly more familiar with the pop items in the test than country western and classical items ($p < .001$). There were no significant differences in familiarity between country western and classical items for either the NH or CI group.

Appraisal

The NH group and CI group were compared on measures of appraisal and perceived complexity using a mixed general linear model, and *t*-tests for pairwise comparisons (SAS, Mixed Procedures). Analyses for implant recipients were further examined by device type and the appraisal scores were correlated with hearing history, speech recognition, and cognition scores. Such comparisons were not appropriate for the NH group.

Liking. Mean scores for liking appear in Table 1. The NH group gave higher ratings, that is, more positive appraisal, on two of the three musical styles than the CI group. A repeated measures analysis of variance revealed significant interactions ($p < .0001$) between group (CI and NH) and genre (classical, country, pop) on the dependent variable, 'liking.' Post hoc analyses (pairwise comparisons) revealed the source of difference to be classical items, which were appraised significantly more positively ($p < .0001$) by the NH group than by the CI group.

Within groups, the NH group distinguished among the three styles of music with regard to liking. More specifically, the NH group assigned significantly higher ratings of liking to classical items compared with country ($p < .0001$) and pop music ($p < .003$). They also rated pop music as significantly more likeable than country music ($p < .006$). With regard to familiarity, NH listeners rated familiar items as significantly more likeable than obscure items (p

TABLE 2
Mean Score for Subjective Complexity

	Factor				
	Classical	Country	Pop	Familiar	Obscure
Normal hearing ($n = 36$)	$M = 55.98$; $SD = 28.49$	$M = 28.98$; $SD = 19.64$	$M = 40.23$; $SD = 23.36$	$M = 41.83$; $SD = 17.56$	$M = 42.66$; $SD = 15.99$
Implant recipients ($n = 66$)	$M = 51.14$; $SD = 27.23$	$M = 39.71$; $SD = 22.51$	$M = 47.33$; $SD = 24.84$	$M = 45.63$; $SD = 11.79$	$M = 47.66$; $SD = 13.20$

< .001). Implant recipients did not differentiate among the three genre for the dependent variable of liking, nor was there a main effect for familiarity.

In order to examine responding to individual song items[2] (12 per genre), the mean score on liking was calculated for each song for the NH group and also for the CI group. The range of mean scores on liking for the 36 items ranged from 66.33 (most likeable) to 36.45 (least likeable) for the CI group and 79.17 to 30.40 for the NH group. The 36 song items were then ranked from most to least likeable and those rankings were then categorized into the top, middle, and lowest thirds. The breakdown into tertiles by genre and by familiarity for liking appears in Table 3a. As the table indicates, at least half of the classical items appeared in the lowest third for liking by implant recipients. It is interesting to note that the two classical items that appeared within the top tertile for the CI group were solo piano items with a simple rhythmic and harmonic structure.

Complexity. The mean scores for subjective complexity appear in Table 2. The higher the score, the greater the complexity (difficult to follow and understand). The implant recipients assigned higher complexity ratings to two of the three genre. A repeated measures analysis of variance revealed a significant interaction ($p < .0004$) between group and genre on the dependent variable of complexity. Post hoc analyses revealed that ratings for complexity by the CI group were significantly higher than those of the NH group for both country western music ($p < .0002$) and pop music ($p < .02$). There was no significant difference between the two groups for classical genre.

Within groups, the NH group showed a very similar within-group response across genre as that of the CI group: The NH group rated

TABLE 3a

Breakdown of Song Items by Genre, Familiarity, and Liking (Tertile Categories)

Song category	Liking—top tertile	Liking—mid tertile	Liking—low tertile
Pop	NH = 50%; CI = 41.6%	NH = 25%; CI = 25%	NH = 25%; CI = 33%
Country	NH = 25%; CI = 41.6%	NH = 25%; CI = 41.6%	NH = 50%; CI = 16.6%
Classical	NH = 25%; CI = 16.6%	NH = 50%; CI = 33%	NH = 25%; CI = 50%
Familiar/ Obscure	NH = 75% familiar, 25% unfamiliar, CI = 83% familiar, 16.6% obscure	NH = 75% familiar, 25% unfamiliar, CI = 66% familiar, 33% obscure	NH = 58% familiar, 41.6% unfamiliar, CI = 50% familiar, 50% obscure

classical genre as significantly more complex than both country ($p < .0001$) and pop ($p < .0001$) and pop as significantly more complex than country ($p < .005$). The CI group also perceived classical genre as significantly more complex than both country ($p < .0001$) and pop music ($p < .004$) and pop as significantly more complex than country ($p < .03$).

In order to examine responding to individual song items, the mean score on complexity was calculated for each song for the NH group and also for the CI group. The range of mean scores on complexity for the 36 items ranged from 29.47 (simplest) to 75.53 (most complex) for the CI group and 15.25 to 78.17 for the NH group. The 36 song items were then ranked from most to least complex and those rankings were then categorized into the top, middle, and lowest thirds. The breakdown into tertiles by genre and by familiarity for liking appears in Table 3b. As the table indicates, 66% of the classical items appeared in the highest third for complexity as rated by implant recipients. It is interesting to note

TABLE 3b

Breakdown of Song Items by Genre, Familiarity, and Subjective Complexity (Tertile Categories)

Song category	Complex—top tertile	Complex—mid tertile	Complex—low tertile
Pop	NH = 33%; CI = 33%	NH = 33%; CI = 33%	NH = 33%; CI = 33%
Country	NH = 0%; CI = 0%	NH = 33%; CI = 58%	NH = 66%; CI = 41.6%
Classical	NH = 66%; CI = 66%	NH = 33%; CI = 8.3%	NH = 0%; CI = 25%
Familiar/ Obscure	NH = 66% familiar, 33% unfamiliar, CI = 75% familiar, 25% obscure	NH = 66% familiar, 33% unfamiliar, CI = 66% familiar, 33% obscure	NH = 66% familiar, 33% unfamiliar, CI = 66% familiar, 33% obscure

that those classical items that appeared within the lowest tertile for complexity were the three solo piano items with a simple rhythmic and harmonic structure, and were also the three highest rated classical items for liking.

The Relationship between Liking and Complexity for the Two Groups

Between Groups

Pearson product-moment correlations between the NH and CI group on the dependent variable of 'liking' for individual song items was $r = -0.03$—that is, the two groups differed greatly with regard to which items they rated as most and least likeable. In contrast, there was a strong positive relationship ($r = .85$) between the NH and CI groups on ratings of subjective complexity for individual song items.

Within Groups

For the normal hearing listeners, there was a moderate correlation of $r = .60$ for liking and complexity, with the NH group showing greater liking of moderately to somewhat more complex items. In contrast, the implant recipients had a strong negative relationship ($r = -.72$) between liking and complexity, thus showing a preference for more simple items.

Additional Analyses for Implant Recipients

On the dependent variable of liking, repeated measures analysis of variance revealed no main effect for device, but a significant interaction ($p < .03$) between genre and device. Differences between devices were significant only for the classical genre: Ineraid and Med-El users' rated classical music as significantly more likeable than CI24M recipients (Ineraid, $p < .04$; Med-El, $p < .002$) and CI22 recipients (Ineraid, $p < .03$; Med-El, $p < .004$); Med-El users appraisal ratings for liking were significantly higher than ratings of Clarion users ($p < .008$). It is important to interpret these differences with caution, however, given the relatively small sample size of Ineraid ($n = 2$) and Med-El ($n = 12$) users in this particular sample. Repeated measures analysis of variance revealed a significant device effect ($p < .03$). Post hoc analyses revealed the differences to be significantly less complex ratings by CI24M users compared with Clarion users ($p < .003$).

TABLE 4

Implant Recipients: Descriptive Statistics for Participant Variables

Variable	Mean	Standard deviation
Age at time of testing	56.22	14.94
Length of profound deafness in years	13.96	13.57
Months of implant use	65.47	44.06
Percent correct on HINT speech test	68.29	31.11
Percent correct on Iowa Consonant Test in Noise	59.57	18.88
Percent correct on Iowa Consonant Test in Quiet	59.49	20.94
Percent correct on Iowa Sentence Test	72.65	28.21
Percent correct on NU-6 test	55.91	24.68
Pre-implant listening habits	5.40	1.99
Post-implant listening habits	4.23	1.82
Elementary school music instruction	6.90	6.76
High school, college, adult music instruction	.76	1.22

Because implant recipients (including persons who use the same type of device and processing strategy) tend to show considerable variability in many speech and music perception outcome measures (Gfeller et al., 2000; Tye-Murray et al., 1992; Wilson, 2000), and because theories of appraisal (e.g., LeBlanc, 1982) indicate the importance of individual listener characteristics in music preference, it is essential to consider characteristics of the individuals that may contribute to implant benefit with regard to appraisal of complex songs. Table 4 provides the descriptive statistics for these measures and Table 5 indicates the Pearson product-moment correlations coefficients among the dependent measures of liking and complexity with the following variables: five measures of speech reception, three measures of cognitive processing, demographic measures for hearing history, and musical listening habits and training of implant recipients. Those variables with the strongest relationships to liking were the three cognitive measures and the extent of time spent in listening to music post implantation (all statistically significant at $p < .0001$).

Discussion

These analyses reveal that implant recipients find listening to complex songs, from the standpoint of appraisal, to be quite different from the experiences of adults with normal hearing. With regard to liking, the normal hearing adults demonstrated distinct stylistic preferences, and they also preferred the familiar to the ob-

TABLE 5

Correlation (Pearson product-moment) Matrix for Implant Recipient Characteristics × Appraisal Outcomes

Variable	Like	Complexity
Age at time of testing	−.09	.02
Length of profound deafness in years	−.03	.07
Months of implant use	−.03	.02
Percent correct on HINT speech test	.08	−.09
Percent correct on Iowa Consonant Test in Noise	.04	−.09
Percent correct on Iowa Consonant Test in Quiet	.09	−.09
Percent correct on Iowa Sentence Test	.01	.09
Percent correct on NU-6 test	−.04	.01
Score on Sequence Completion Test	.20	−.05
Z-Score on VMT1	.24	−.04
Z-Score on VMT2	.25	−.08
Pre-implant listening habits	.10	−.10
Post-implant listening habits	.22	−.02
Elementary school music instruction	.03	−.07
High school, college, adult music instruction	.11	−.04

scure items. In contrast, the CI group gave very similar ratings for liking to the three different genres, and familiarity was a significant factor with regard to liking only for pop items. It is likely that CI users receive such an altered or degraded representation of the music that they cannot differentiate in a meaningful manner among the three genre, or consistently recognize songs that were familiar prior to hearing loss. This supposition is supported by prior studies of song recognition which indicate that implant recipients are significantly less accurate in being able to recognize complex songs in open set (either by song title or by style) than are normal hearing adults (Gfeller et al., 2002).

In general, the data for the NH group support the influence of subjective complexity and familiarity with regard to liking, as has been hypothesized in optimal complexity theory. The notion of what constitutes optimal complexity, however, appears to be significantly altered for implant recipients as a result of the atypical signal transmitted. That is, implant recipients show a strong preference for much musical sounds that they perceive as more simple. For example, implant recipients rated classical music as significantly more complex than the pop and country styles of music, and they also rated classical music as significantly less likeable than did normal hearing listeners. Furthermore, the strong negative correlation between liking and complexity indicates that CI recipients tended to give higher ratings toward songs that they considered to be less complex. This is in contrast to the positive correlation of complexity and liking among normal hearing listeners, who tended to prefer songs with moderate or slightly greater complexity.

There are several plausible explanations why the CI group rate classical music as more complex than country or pop music. First, from the standpoint of objective complexity, the structural characteristics of classical music tend to be more complex (e.g., use of complex rhythmic structures, more complex harmonic changes, contrapuntal organization with multiple melodic themes, etc.) than pop or country music. Both pop and country music tend to have short simple melodies built over simple and repetitive rhythms and harmonic changes. The melodies and choruses are often repeated many times, and there is considerable structural redundancy within all aspects of the music and lyrics. The fact that the NH group also rated classical items as the most complex of the three genre tested in this study indicates that classical music also tends to be subjectively more complex, even when the peripheral hearing mechanism functions normally.

However, for implant recipients, there is most likely an additional factor regarding complexity related to device features. The cochlear implant has been developed primarily to transmit speech sounds. In this particular test, both the pop and country western items had lyrics (speech-type information) while the classical items did not. Although not all implant recipients are able to extract linguistic information from sung lyrics, some can. Thus, for some implant recipients, the lyrics in pop and country music may have provided enough useable acoustic information to more easily follow the sequence of events. In addition, a strong, simple beat, which is effectively transmitted by implants, is often a characteristic feature of both pop and country music. Therefore, both pop and country western styles are likely to contain structural features more suitable for transmission through current day implants (thus, reducing the objective complexity) than do instrumental classical songs. Further study is underway to compare appraisal of these three genre, but with balanced item representation for vocal and instrumental music. These studies may help to clarify the role which linguistic material (lyrics) plays in complexity and liking for implant recipients.

Only in the case of pop music did prior song familiarity appear to have a significant impact on liking or subjective complexity. Perhaps this is because both the CI and NH group had the greatest prior familiarity with pop items, and therefore the influence of prior familiarity was more pronounced for this one genre. However, with regard to CI users, it is important to keep in mind that implant recipients have significantly poorer recognition of previously familiar songs than do normal hearing listeners. Therefore, the influence of prior familiarity is strongly mitigated by inability to recognize previously familiar songs. In short, the poor transmission of key structural features of music by current-day cochlear implants overwhelms other potentially influential factors such as prior familiarity, social status, musical training, and peer influence described in LeBlanc's interactive theory of musical preference. This is likely to be particularly true in this testing format (open set, no feedback) in which the participant has no cues regarding the style or social context of the music being heard (as may be available in a live concert, on TV or in movies, or even when listening to radio or records if the listener has access to song titles or verbal commentary by the radio disc jockey).

With regard to differences in liking and complexity based on implant type, no device seems clearly superior for music appraisal of complex songs. Higher appraisal by Ineraid users could possibly be attributed to an analog signal, which may be more suitable than the pulsatile feature extraction or spectral representation of the other devices for instrumental music. However, only two CI users in this sample used the Ineraid; thus those data must be interpreted with considerable caution. The superior performance for classical items by Med-El recipients ($n = 12$) must also be interpreted with caution because one Med-El user was a professional musician who dedicated considerable effort to systematic music training and exposure postimplantation—especially for classical genre. Her mean liking score for classical items was 80.53 (more than one *SD* above the mean for most CI users), and her mean scores of 27.2 for pop and 24.8 for country were each more than one *SD* below the mean for those two genre. With a sample size of 12 Med-El users, an outlier can assert undue influence upon the analyses.

It is interesting to note that cognitive processing and postimplant listening habits were those variables most strongly related to liking. These findings are consistent with several prior studies regarding music perception and enjoyment (Gfeller et al., 1997; Gfeller et al., 1998; Gfeller et al., 2001). This suggests that the ability to follow and enjoy a complex signal that has been significantly degraded in the signal processing is likely influenced by how effectively and efficiently an individual can process a sequential signal, and the extent of dedicated practice (with feedback) in listening to music post implantation.

Although the implant recipients tended to rate the complex songs less positively and with a more restrictive range than did the NH group, it is interesting to note that the differences were significant for only one of the three genres. Although one might anticipate a greater difference with regard to liking for all genres, given the atypical representation of pitch and timbre, these findings are consistent with measures of self-report in other studies (Gfeller et al., 2000)—that is, implant recipients do not consider music listening as uniformly unpleasant, or some have come to accept a different idea of musical sound as preferable to no music. Some implant recipients (approximately 33%) do consider music to be so aversive in sound (e.g., like noise, like a bunch of squawking parrots, etc.) that they purposefully avoid music. About 43% report either that some music is improving with practice, or that they prefer hearing music to nothing, though it is less pleasant than prior to deafness. About 25% listen to music regularly and report that they find some (though not all) music to be enjoyable and meaningful under particular circumstances.

Questionnaire data in prior studies reveal that a quiet listening environment is essential to enjoyment (Gfeller et al., 2000). Testing for this study was conducted in a sound treated room, with sound levels normalized for comfort. Thus, these outcomes should be generalized only to other similar acoustical environments. This test format was less advantageous, however, on other factors, which can enhance musical enjoyment. For example, prior knowledge of what music one is about to hear, being able to follow along with the music or watch the performer, or listening as part of a meaningful social event all can enhance music enjoyment. Such factors are consistent with a number of the factors noted in LeBlanc's interactive theory of music preference. Thus, it is the case that music appraisal is not just a matter of the cleanliness and structural features of the acoustic signal. Rather, it can be influenced considerably by the listening environment, respondent action variables, and social influences.

In conclusion, these results support optimal complexity and interactive theories of music appraisal among normal hearing listeners. However, for postlingually deafened adults who use cochlear implants, the cochlear implant is such a significant mitigating factor that the structural features of the signal appear to overwhelm many of the factors in interactive theories of music that would normally enhance music listening. Changes in implant design are most likely necessary before the majority of implant recipients will be able to achieve a normal level of musical enjoyment for complex real-life songs. However, implant recipients can optimize their enjoyment at least to some extent by careful selection of the listening environment and music that is structurally more accessible and less complex, and by utilizing environmental cues to assist in cognitive processing of the acoustic signal.

These outcomes also have potential applicability to the expanding cohort of adults age 65 and older, many who have at least moderate hearing losses and who use conventional hearing aids. Current day hearing aids are far from ideal with regard to transmission of musical sounds, particularly in cases where mere amplification is an inadequate solution (e.g., cases of sensorineural hearing losses with considerable nerve damage). The findings of this study underscore the many factors that influence music listening, and may suggest practical accommodation or rehabilitative strategies that can optimize musical enjoyment for the many hearing aid recipients for whom music listening has been a meaningful life experience.

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End Notes

1. The *Iowa Medical Consonant Test* assesses the individual's ability to select in closed set the correct consonant sound that is embedded in a 2-syllable nonsense word (vowel-consonant-vowel format). The *NU-6 Words Test* requires the participant to repeat monosyllabic words in an open set. The *HINT* requires the participant to repeat full sentences in open set. The *CNC* is a word recognition test in which the participant is asked to repeat monosyllabic words (consonant-nucleus-consonant format) presented in open set.

2. Because this test is still in active use, and no feedback is given regarding the titles or styles of individual selections, the names of specific song items are not listed in the article in order to reduce inadvertency in revealing song titles to potential participants.

Appendix

Although there are variations in the design of implants manufactured by different companies, there are basic components found in most devices. An external microphone receives sound and converts it into an electrical signal. This signal is sent to an externally worn signal processor, which can be programmed in a variety of ways. Because the device was designed primarily with speech perception in mind, cochlear implants transmit those features of the sound wave that are believed to be especially salient to speech perception. There is still considerable debate on the optimal form in which speech should be electrically delivered to the auditory nervous system, consequently, a variety of coding strategies are used in the various devices. For example, some strategies (e.g., Ineraid device with analog signal) provide a direct electrical representation (analog) of the speech signal. Others extract particular formants (e.g., F0, F1, F2) or high-energy aspects of the spectral envelope of the input signal and deliver a digital (pulsatile) signal (e.g., MPeak, SPEAK, CIS, ACE) to the electrode array. Most implants transmit different relatively broad ranges of frequency to different electrodes within the cochlea, and do not present the fundamental frequency of the signal. The present generation of devices delivers primarily high frequency information (e.g., 2000–4000 Hz), because this is the range in which sounds critical to speech perception are produced. The coded signal from the processor is transferred directly by wires through the skin or across the skin to a package of electrodes implanted in the inner ear, where an array of electrodes excites the cochlear neurons of the auditory nerve. In some devices, the coded signal is delivered to the electrode array as one channel of information, or it is split into several channels and delivered independently to different electrodes. The Clarion (8 electrodes), CI22 (22 electrodes), CI24M (24 electrodes), and Med-El (6 electrodes) processors vary in the number of electrodes implanted internally within the cochlea.