Published in final edited form as:

J Music Ther. 2015 ; 52(1): 78–116. doi:10.1093/jmt/thu039.

Do Communication Disorders Extend to Musical Messages?: An Answer from Children with Hearing Loss or Autism Spectrum Disorders

Christina M. Whipple, MA,

School of Music

Kate Gfeller, PhD,

School of Music, Department of Communication Sciences and Disorders

Virginia Driscoll, MA,

Iowa Cochlear Implant Clinical Research Center, University of Iowa Hospitals and Clinics

Jacob Oleson, PhD, and

Department of Biostatistics

Karla McGregor, PhD

Department of Communication Sciences and Disorders, TheDeLTA Center, The University of Iowa

Abstract

Background—Effective musical communication requires conveyance of the intended message in a manner perceptible to the receiver. Communication disorders that impair transmitting or decoding of structural features of music (e.g., pitch, timbre) and/or symbolic representation may result in atypical musical communication, which can have a negative impact on music therapy interventions.

Objective—This study compared recognition of symbolic representation of emotions or movements in music by two groups of children with different communicative characteristics: severe to profound hearing loss (using cochlear implants [CI]) and autism spectrum disorder (ASD). Their responses were compared to those of children with typical-development and normal hearing (TD-NH). Accuracy was examined as a function of communicative status, emotional or movement category, and individual characteristics.

Methods—Participants listened to recorded musical excerpts conveying emotions or movements and matched them with labels. Measures relevant to auditory and/or language function were also gathered.

Results—There was no significant difference between the ASD and TD-NH groups in identification of musical emotions or movements. However, the CI group was significantly less accurate than the other two groups in identification of both emotions and movements. Mixed

effects logistic regression revealed different patterns of accuracy for specific emotions as a function of group.

Conclusion—Conveyance of emotions or movements through music may be decoded differently by persons with different types of communication disorders. Because music is the primary therapeutic tool in music therapy sessions, clinicians should consider these differential abilities when selecting music for clinical interventions focusing on emotions or movement.

Keywords

music perception; autism; cochlear implants; children; communication; music recognition; emotion; movement

Introduction

What is communication? According to Gillam, Marquardt and Martin (2000), communication is any exchange of meaning, whether intended or unintended. Owens describes communication as

“the process participants use to exchange information and ideas, needs and desires. The process is an active one that involves encoding, transmitting, and decoding the intended message It requires a sender and a receiver, and each must be alert to the informational needs of the other to ensure that messages are conveyed effectively and that intended meanings are preserved (p. 11, 2001).”

While these definitions were written with spoken, gestural, or written language in mind, they also characterize music, long considered a form of communication, despite its lack of specific designative meaning (Gfeller, 2008, 2012a; Patel, 2010). Musical communication is central to music therapy practice; consequently, the extent to which the intended message is properly conveyed is an important clinical consideration. With clients who have communicative disorders, it is possible that the disorder may interfere with receipt of the intended meaning of musical as well as spoken communication. Thus, it is important for music therapists to ascertain whether intended messages in music are preserved sufficiently for therapeutic uses, or if specific modifications are warranted.

This paper focuses on persons with two types of communicative disorders served by music therapists, who have deficits based in different etiologies, and whose specific communication characteristics differ: severe/profound hearing loss (damage to the peripheral hearing mechanism), and autism spectrum disorder (ASD) (central deficits). The comparison of these two groups emphasizes that the specific characteristics of a particular communication disorder may require different clinical approaches. While musical communication comprises various aspects and levels of perception and meaning, the focus of this paper is on conveyance of symbolic meaning in which musical sounds denote or refer to either emotions or physical movements (Gfeller, 2008, 2012a; Juslin & Sloboda, 2010; Thaut, 2005). Both emotions and movement are important functional domains commonly addressed through music therapy interventions (Gfeller, 2008; AMTA, 2013); consequently, the extent to which music can effectively convey these aspects of human experience to clients who have specific communication disorders is of clinical relevance.

Literature Review

Music and symbolic conveyance of emotions and movements

Research indicates that music conveys emotional content through cultural conventions and psychophysical cues. The term “cultural convention,” within the context of musical communication, refers to musical patterns (e.g., specific scales, ragas) that, through common use have become standardized and efficient in conveying particular emotions and other symbolic meaning (Balkwill & Thompson, 1999; Kwoun, 2009). Psychophysical cues are structural features of music, such as tempo, mode, and articulation. Cues such as tempo (fast vs. slow) and mode (major vs. minor) are particularly effective in depicting emotional connotations in music across different cultures, and even with very young children (Gabrielsson & Lindstrom, 2010; Juslin & Sloboda, 2010; Juslin & Timmers, 2010). However, some emotions are more easily conveyed in music than others (Juslin & Sloboda, 2010), and subtle emotional categories are better recognized by older rather than younger children (Dowling, 1999) and within rather than between cultures (Balkwill & Thompson, 1999; Kwoun, 2009). It is important to note that in research on music and emotions, clear distinction is made between the ability of the listener to recognize emotions within musical excerpts vs. the ability of music to actually elicit an emotional response in the listener (Juslin & Sloboda, 2010). While both are important, the present study focuses on recognition as opposed to elicitation of emotions.

From a functional standpoint, music provides useful cues of suitable emotional responses to a given situation (e.g., sad music during funerals; happy music for celebrations), and music is also often used for mood management (Gfeller, 2008; North, Hargreaves, & O’Neill, 2000; Saarikallio, 2007). Because music is effective in conveying emotions and moods, it can be a useful tool in music therapy for interventions intended to foster awareness, exploration, or expression of emotions (Gfeller, 2008, 2012b).

Music can also convey cues regarding physical movement, such as rate (e.g., faster or slower), manner (e.g., even or syncopated patterns for walking vs. skipping), or direction (e.g., moving higher or lower) (Gfeller, 2008, 2012b; Thaut, 2005). From a functional perspective, music organizes and supports rhythmical movements such as marching (duple meter), dance (e.g., triple meter for waltz; syncopated beat for salsa), and creative movement (e.g., musical patterns representing reaching or crawling).

A growing body of research has examined structural components of music (especially rhythm) to facilitate neuromuscular efficiency in persons with neurological disorders (Gfeller, 2008; Thaut, 2005) or to enhance motor development in children (Gfeller, 2008; Thaut, Thaut, & LaGasse, 2008). Music can also represent movements in a symbolic fashion (Thaut, et al., 2008) with the rates and melodic patterns implying images associated with movement (e.g., crawling, climbing) that can be used in creative or improvisational movement. However, to date, systematic study of this aspect of musical communication is limited (Heaton Allen, Williams, Cummins, & Happe, 2008).

In short, musical symbols can be used to convey emotions and movements, thus music may serve as a valuable tool for therapeutic and educational goals and objectives for which these

functional domains are relevant. To function as an effective therapeutic tool, however, the music must preserve and convey the intended message in a manner sufficiently perceptible to the receiver (Owens, 2001). If the receiver has a communication disorder that impairs transmission or decoding of the structural features or symbolic content, the intended message may be imperceptible or distorted. The present study examines perception of symbolic musical communication by persons with two distinctly different types of communication disorders: severe/profound hearing loss, and autism spectrum disorder (ASD).

Musical communication and hearing losses

Hearing losses can vary on numerous factors including onset (e.g., prelingual, postlingual), severity (e.g., mild to profound), and type (e.g., sensorineural, conductive). Losses of earlier onset, of greater severity, and that are sensorineural (damage to the inner ear) tend to have more negative impact upon transmission or decoding of musical communication. Even persons with more severe losses may have relatively 'normal' perception of temporal aspects of music (e.g., tempo, rhythm) through residual hearing or vibrotactile means (Gfeller & Darrow, 2008; Limb & Roy, 2014). However, severe sensorineural losses, which involve considerable damage to the auditory pathway, are likely to reduce spectro-temporal resolution (Limb & Roy, 2014) and thus impair perception of pitch (and thus, melody and harmony) and timbre (Gfeller & Darrow, 2008; Looi, Gfeller, & Driscoll, 2012). Furthermore, a more severe congenital or prelingual onset limits exposure to 'normal' representation of musical sounds (especially pitch and timbre), and possibly exposure to symbolic uses (e.g., motifs or music to convey thematic content in films) of music. Thus, persons with severe and early hearing losses may perceive emotional content within music differently from normal hearing (NH) persons (Darrow, 2006; Darrow & Loomis, 1999).

Perception of musical structures is also impacted by the technological constraints of hearing devices (e.g., hearing aids [HAs], cochlear implants [CIs]) in encoding and transmitting spectrally-complex features such as melody, harmony, and timbre (Gfeller & Darrow, 2008; Looi, et al., 2012). For mild to moderate losses, conventional HAs do transmit the pitch and timbre, thus many psychophysical cues that help to convey emotions or movements in music can be accessed (Gfeller & Darrow, 2008). For persons with severe to profound losses, who are the focus of this study, conventional HAs provide limited benefit; consequently, persons with severe to profound losses may choose to use CIs. [For detailed information regarding CIs, see Looi, Gfeller, & Driscoll (2012).]

In relation to music perception, it is notable that present-day CI processing strategies usually remove the temporal fine-structure information in the stimulus waveforms and preserve the temporal envelopes extracted from 6 to 22 frequency bands; these are conveyed via the electrodes in the internal array. The electrode array has a small number of wide bandpass filters with fixed center frequencies, resulting in coarse spectral cues, and thus poor frequency resolution. This signal is effective in conveying the rhythmic components of music, but is poorly suited for transmitting greater fine structure required for perception of pitch (and thus melodies and harmonies) and timbre (Gfeller et al., 2008; Looi, et al., 2012). Thus, most CI recipients are significantly less accurate than NH individuals in perception of

melody and harmonies (including major vs. minor modes) as well as timbral qualities (e.g., mournful or bright sound quality) (Gfeller et al., 2008; Looi, et al., 2012). Relative to the research questions in this study, because mode (e.g., major vs. minor) and timbre are two structural features that, for NH persons, have often been associated with conveyance of emotions (e.g., Juslin & Sloboda, 2010; Kwoun, 2009), it seems likely that CI recipients may have difficulty recognizing emotions conveyed by melodic or timbral cues.

Preliminary research (Hopyan, Gordon, & Papsin, 2011; Hopyan et al., 2012) indicates that children who use CIs are able to perceive happy vs. sad emotions conveyed by music at a level well above chance, but significantly less accurately than children with normal hearing. Furthermore, they tended to rely on rhythmic cues, such as slow or fast tempo, to differentiate between sad vs. happy excerpts. However, the children with CIs showed greater accuracy in differentiating between happy and sad musical excerpts compared with happy or sad affect (emotional prosody) conveyed in spoken sentences. Thus, it has been posited that the rhythmic/tempo cues in music may offer a useful clinical tool for helping children who use CIs to understand emotional affect (Gfeller, Driscoll, Kenworthy, & Van Voorst, 2011; Hopyan et al., 2011; Hsiao & Gfeller, 2012).

While it is a positive indication that music can assist pediatric CI users to differentiate between happy and sad emotions, in everyday life, people experience a much wider range of emotions than just happy and sad. Prominent among psychological explanations of human emotions is a categorical theory, which posits that humans experience five basic emotions from which all other emotional states can be derived (Juslin & Sloboda, 2010 and Niedenthal, Krauth-Gruber, & Ric, 2006). Therefore, it is of interest whether children with CIs are able to differentiate among the five recognized basic emotions. Our study expands upon currently available knowledge regarding children with CIs, and their recognition of these five basic emotions as conveyed through music.

Regarding movement cues in music, because children with CIs are quite accurate in perceiving tempo and rhythm, accessible temporal features should offer useful timing cues for symbolizing the rate and manner of physical movements (e.g., walking, skipping, running) used in creative movement exercises or physical rehabilitation (e.g., Hsiao & Gfeller, 2012). However, some children with CIs may have been included less frequently in music-based instruction or social experiences (Gfeller, Driscoll, Smith, & Schepelerle, 2012), thus, they may have had fewer opportunities to learn common symbolic associations between particular musical structures (including tempo) and movements. To date, this aspect of musical communication has not been systematically examined with this population, thus, motivating the present study

Musical Communication and Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is neurodevelopmental disorder characterized by two core symptoms: (a) persistent deficits in social communication and social interaction across multiple contexts, and (b) restricted, repetitive patterns of behavior, interests or activities. (DSM-5TM, American Psychological Association, 2013). Because of notable variability among persons with ASD in regard to severity and specific subtypes, it is difficult to make generalizations regarding capabilities and deficits of individuals. However, communication

deficits common to individuals with ASD include expressive and receptive language deficits, poor nonverbal (facial and gestural) communication skills, and pragmatic deficits that manifest as sharing too much, not enough, or irrelevant information with communication partners. While these deficits represent an impediment to social interaction, such interactions are further reduced by deficits in understanding or responding to another's emotions in an appropriate way, and lack of affective prosody (prosodic features that convey emotions) (Baron-Cohen, Golan, Wheelwright, Granader, & Hill, 2010; Kern, 2013; McCann, Peppe, Gibbon, O'Hare, & Rutherford, 2007).

Individuals with ASD may have difficulty assessing, processing, and producing emotional affect conveyed via voice, eyes, and accompanying facial expressions (Bal et al., 2010; Bauminger & Kasari 2000; Rutherford & McIntosh, 2007; Volker, Lopata, Smith & Thomeer, 2009). In this population, deficits in perceiving emotion are not the result of peripheral damage as is the case with hearing losses. That the deficit can be present in both auditory and visual modalities suggests a more central mechanism, with fMRI data revealing under-activation of the amygdala in response to emotion-laden inputs (Baron-Cohen, et al., 2000). Moreover, adolescents with ASD who were given oxytocin, a neuropeptide that enhances dopamine-dependent reward and reduces anxiety via amygdala-dependent mechanisms, demonstrated improved perception of emotion as expressed in the eyes (Guastella, et al., 2010).

Given documented problems with verbal communication, and particular problems with the processing of emotion in faces, eyes, and speech, it is noteworthy that some (though not all) children with autism are sensitive to and prefer music to other stimuli (including speech); some even show enhanced performance on pitch tasks (Adamek et al., 2008, O'Riordan & Passetti, 2006). Because music is of particular interest to some children with ASD, researchers have studied whether children with autism are more accurate in decoding emotional content in music compared with spoken communication. Several studies indicate that children with ASD were similar to TD peers on recognizing happy or sad emotions in short sequences of music primarily based upon major and minor modes (Kastner & Crowder, 1990; Heaton, Hermelin, & Pring, 1999; Heaton, Allen, et al., 2008). Emotion recognition was more closely related to the participants' verbal mental age than their diagnosis. Because prior research indicates that music can be effective in conveying basic emotions to persons with ASD, clinicians and researchers have hypothesized that music may be both motivating and effective as a therapeutic tool for improving recognition or expression of emotions, communication, and social skill acquisition (e.g., Allen & Heaton, 2010; Boso, Emanuele, Minazzi, Abbamonte & Politi, 2007; Gold, Wigram, & Elefant, 2006; Heaton, Allen, et al., 2008; Kaplan, 2005; Katagiri, 2009; Molnar-Szakacs, et al., 2009). From a methodological perspective, it is of interest that prior studies may have examined fewer or different categories of emotions (Heaton, Hudry, et al., 2008), or may have measured intensity of emotions (Bhatara et al., 2010); further study of all the basic emotions in relation to the ASD population is of interest.

Although few studies have examined recognition of symbolic categories of movement through music in individuals with ASD (O'Conner, 2012); in 2008, Heaton, Hudry, and colleagues compared recognition of symbolic representation of movements by persons with

ASD with typically developing children and adults and persons with Down Syndrome. This task was utilized, in part to contrast recognition of non-affective information with the emotional excerpts conveyed through music. Of particular interest was their finding that children with ASD were more accurate with recognition of emotions than movements. In the current study, we not only wished to re-examine several questions introduced by Heaton, Hudry, et al., (2008), but we also saw the category of movement as inherently interesting, given the common usage of music to support creative movement within music therapy sessions.

The aforementioned studies suggest that at least some emotions and movement may be conveyed through musical communication to either children with CIs or ASD at least above chance if not comparably to TD children. Thus, music may be an effective therapeutic tool for exploring expression of emotions or movement-related interventions. However, given the diverse characteristics within these two populations (hearing loss, ASD), the variety of participant characteristics in extant studies, and specific methodological differences in selection of musical excerpts, emotions, and response tasks in prior studies, questions remain in relation to sample characteristics, stimuli parameters and response tasks (Bal et al., 2010; Gfeller, Driscoll, et al., 2012; Heaton, Allen, et al 2008; Hopyan et al., 2012; Hsiao & Gfeller, 2012; Juslin & Sloboda, 2010; Rutherford & McIntosh, 2007; Silani et al., 2008; Volker et al., 2009).

The purpose of this study was to examine children's recognition of symbolic representation of emotions or movements within musical excerpts. The target task for this experiment should not be confused with production of emotional responses or movements in response to the music (Juslin & Sloboda, 2010). Recognition accuracy was examined as a function of communication characteristics (severe/profound hearing loss with CI; ASD; a comparison group of typically developing children with normal hearing [TD-NH]). The two categories of communication disorders permitted comparisons of the impact of two contrasting etiologies: damage at the peripheral level (hearing loss) and communication deficits involving a more central mechanism. While perceptual accuracy of psychophysical features certainly impacts the resulting outcomes, the dependent variable for our study was recognition of symbolic meaning, as opposed to the examination of perceptual processing of psychophysical features.

We asked the following research questions: Does accurate recognition of symbolic representation of emotions in musical excerpts differ as a result of communicative status (CI, ASD, TD-NH)? Are some emotions more easily identified by specific groups than others? Does accurate recognition of symbolic representation of movement in musical excerpts differ as a result of communicative status (CI, ASD, TD-NH)? Are some movement cues more easily identified by specific groups than others? Does accurate recognition of emotional content or movement in music differ as a result of relevant individual characteristics?

Method

Participants

This experiment compared two groups of children with communicative disorders of differing etiologies: (a) 26 children with severe/profound hearing loss who use cochlear implants (17 males, 9 females) with a mean age of 12.38 (SD=3.14; range=8–18) and (b) 24 children with a primary diagnosis of Autism Spectrum Disorder (ASD) (22 males, 2 females) and a mean age of 14.25 (SD: 2.21, range: 10–18). Their outcomes were compared with those of 35 children who were typically developing and normal hearing (TD-NH) (16 males and 19 females), with a mean age of 11.06, (SD: 2.84, range: 6–17). The participants in the CI and ASD groups were recruited from two separate existing databases of enrollees in other studies at the university. Those in the TD-NH group were recruited through advertisements or through enrollment in previous research on language development at the university. Participants from all three groups spoke English as their primary language, grew up in the United States, and had no comorbid conditions that would affect their ability to perform the tasks. Recruitment and testing were conducted in compliance with the university's IRB.

CI Group—As noted previously, the term, hearing loss, encompasses a population that varies on a host of factors (e.g., onset, severity, type, configuration). Recruitment for the CI group took place at a pediatric cochlear implant center at a large Midwestern university hospital. Within this center, pediatric services extend to children from birth through age 18. For the present study, criteria included an age of at least 7 years, severe to profound prelingual hearing loss, and at least 12 months of CI use. The group members used a variety of device types (CI24M, Freedom, Contour, CI512, 90K) configurations (13 unilateral, 10, bilateral, 3 bimodal) and processing strategies (ACE, HiRes 120) (For additional information regarding technical characteristics of different types of cochlear implants in relation to music, see reviews in Looi, Gfeller & Driscoll, 2012 and Limb & Roy, 2014).

Because of the enormous variability on a host of factors found among persons with hearing loss, including only CI recipients in this hearing loss group resulted in a sample with more homogeneous auditory characteristics (e.g., severity, type) and signal input characteristic (good temporal cues but poor spectral cues transmitted via the CI), and thus greater group consistency regarding psychophysical cues encoded and transmitted. This assisted in greater clarity in data interpretation. Those in the CI group were tested on the PEMM instrument (described below) during annual visits to our Cochlear Implant Clinical Research Center. After accommodating the assessment requirements of the entire clinical team (e.g., audiology, speech and language), which is an important practical consideration with regard to time for testing, 20 of the 26 CI group members were also assessed on the Peabody Picture Vocabulary Test–III (PPVT, described below) (Mean=81.6; range of 40–101, SD=16.92); 26 completed questionnaires regarding extent of enrollment in music instruction (questionnaire properties are described in Stordahl, 2002) (Mean = 6.19; range of 1–16, SD= 3.62).

ASD Group—Autism Spectrum Disorder is a diagnosis that also encompasses persons varying greatly on a number of factors. In order to have a more homogeneous sample for testing, which would facilitate interpretation of results, we recruited participants from an existing research database of individuals who had already been assessed and were determined to have sufficient behavioral, cognitive and language skills needed for completion of the experimental tasks. Participants enrolled in the database had a chronological age between 10 and 18, NH, and a confirmed diagnosis of (ASD), based upon the algorithm on the Autism Diagnostic Observation Schedule (ADOS) (Lord, et al., 2008). The ADOS is a standardized approach to observing and coding social and communicative behaviors as the participant interacts with the examiner in a variety of activities such as play (for those functioning at younger levels) and answering interview questions (for those who are functioning at adolescent or adult levels and are verbally fluent). Because of empirical evidence of its validity and reliability, the ADOS is recommended as part of “best practice” in the diagnosis of ASD (National Research Council, 2001). According to research-based recommendations, scores on the communication + social scale of 10 and above indicate autism while scores of 7 and above indicate broader autism spectrum disorders. The participants reported here had mean communication + social scores of 13.88 (range=7–20, SD=4.00).

The TD-NH group acted as a comparison group to establish a ‘typical’ range and central tendencies for children with typical communicative capabilities on the target communicative task. Our criteria for the TD-NH group included native speaker of English, ability to provide consent to participate, and no known cognitive, developmental, or communicative disabilities. Normal hearing criteria, determined through a hearing screen, was established as a pure-tone average 20dBHL across 250, 500, 1000, 2000 and 4000 Hz. Because language development of children with either hearing loss or ASD is sometimes delayed (Gfeller & Darrow, 2008; Adamek, Thaut & Furman, 2008), we recruited TD-NH children who were slightly younger than those in the CI and ASD groups. Due to the potential difficulties associated with selecting all relevant characteristics on which to match all three test groups, we addressed the potential influence of chronological age as part of our statistical analyses rather than attempting to provide age matching for each participant.

Measures

Perception of Emotions and Movement in Music (PEMM) test—The primary outcome variables of interest for the study were scores resulting from the Perception of Emotions and Movement in Music test (PEMM). The PEMM was developed for this study to test children’s ability to recognize the intended symbolic representation in musical excerpts of (a) five basic emotions (Juslin & Sloboda, 2010) and (b) four common physical movements. The protocol was modeled after several prior studies (e.g., Heaton, Allen, et al 2008; Juslin, 2000; Kwoun, 2009) examining recognition of emotions and/or movement in musical excerpts, including several studies with persons who have ASD.

Development of Musical Stimuli: While some studies (e.g., Heaton, Allen, et al., 2008, see extensive review in Juslin & Sloboda, 2010) have utilized excerpts of recorded classical repertoire, we used original tunes composed expressly for this study to avoid pre-existing

associations with movies, cartoons, etc. that could trigger pre-determined emotional content. The excerpts were composed and performed on violin by the first author, whose undergraduate degree was in violin performance. The violin was chosen for preparing the stimuli because prior studies (Juslin, 2000; Kwoun, 2009) determined that string instruments are effective at conveying a wide range of emotions. Examples of excerpts representing several of the categories appear in figure 1.

The compositional characteristics of the emotion excerpts were chosen to be consistent with theoretical principles from psychology regarding basic human emotions (e.g., five basic emotions discussed previously, as well as dimensional accounts, which include pleasant vs. unpleasant and activated vs. deactivated characteristics) (e.g., Ekman, Friesen, & Ellsworth, 1982; Niedenthal, Krauth-Gruber, & Ric, 2006) and prior research studies investigating expression of emotions in music (for review, see Juslin & Sloboda, 2010). As noted previously, research on expression of emotions in music indicates that listeners often rely on psychophysical cues (e.g., tempo, mode, articulation), as well as cultural conventions (or conventional musical patterns). The research review yielded several trends, summarized in Table 1 (e.g., Ekman, Friesen, & Ellsworth, 1982; Gabrielsson & Lindstrom, 2010; see review of literature in Juslin & Sloboda, 2010; Kwoun, 2009), which informed the compositional techniques chosen for newly-composed items representing the five emotions.

Some structural features used in the excerpts were unique to specific target emotions; other features were shared by several emotions. For example, of the five basic emotions, only happy would be considered through dimensional models of emotions to have a pleasant dimensional valence. Thus, of the five emotions, only happy was characterized by major mode. However, greater activation, and thus, brisker tempos are associated with the basic emotions of happy, anger and fear.

In keeping with prior studies of conveyance of emotions through music (see Juslin & Sloboda, 2010), the excerpts for anger, disgust, and fear all shared common elements of narrow pitch variation and complex/dissonant harmonies. Anger and disgust while having different tempi shared minor mode; anger and fear shared fast tempi as well as dissonance. Sadness and disgust shared structural characteristics of minor mode and slow tempo. Because of shared features, differentiation among emotions often requires multiple cues (e.g., tempo, mode, articulatory gestures), or what is called “summary of cue utilization” in order to make each emotion as clear as possible (Juslin & Timmers, 2010), including tempo, articulation, attacks, sound level, vibrato, microintonation, etc. The shared use of features such as fast or slow tempo can also be explained in part by dimensional or circumplex models of emotion (Juslin & Sloboda, 2010; Niedenthal, Krauth-Gruber, & Ric, 2006), which characterize emotional categories on a continuum of low to high arousal and also negative to positive valence.

As noted previously, movement categories were included in prior studies on persons with ASD by Heaton, Hudry, et al., (2008) as a comparison task to emotionally-laden items. At present time, limited prior research exists regarding symbolic representation of movement. Consequently, the Heaton, Hudry, et al., (2008) article acted as a model for our stimuli and response tasks. Initially, the first author prepared a pool of items to represent all five

movements categories (walking, running, skipping, jumping, climbing) used in the Heaton, Hudry, et al. (2008) study. Mood, as is conveyed through structures such as major vs. minor, was not identified to be salient to conveyance of movements. Rather, movement excerpts were characterized by tempos associated with the rate of movement (e.g., walking represented by 60 beats per minute (bpm) versus running at 134 bpm), rhythmic patterns (e.g., even note duration for repetitive movements like walking and running, syncopated for skipping), and melodic patterns conveying change in elevation. Movements of walking, running, and skipping can all be accomplished on one horizontal plane; jumping and climbing, by their very nature, involve change in elevation as well as temporal aspects. Thus, melodic patterns (e.g., lower to higher pitches) indicated changes in elevation in the movement. All excerpts were in major mode, thus melodic contour for climbing was the only pitch-based cue relevant to the final four movement categories.

Pilot testing: Because the stimuli were composed specifically for use in this study, we conducted pilot testing with 17 adults (ages 24–55) and 7 children (ages 6–15) with typical development and normal hearing to determine that the intended categories could be ascertained at a level well above chance. Children with ASD and CIs were not included on the pilot testing due to the limited population available for testing. While we acknowledge that piloting the test stimuli with only the TD-NH group could have influenced the outcome of the study, professionals associated with speech-language development and the ASD population provided feedback regarding the test and its set up, and its suitability for the two groups with communication disorders. Piloting also provided the opportunity to determine that the testing protocol was suitable for children of the age range of those in our sample. Data from the pilot study were not included in the final test analyses. A pool of 40 stimulus items (4 items for each of 5 emotion and 5 movement categories) with compositional features based upon prior studies was composed and recorded by the first author. All 40 items were tested in pilot testing to ascertain those yielding the most accurate responses.

Pilot scores for the emotion items: The mean scores for accuracy across all 20 emotion items were 94.7% correct for the TD-NH adults and 71.4% for the TD-NH children. The higher accuracy rate by adults is consistent with prior research regarding age and accurate recognition as a function of age (Juslin & Sloboda, 2010). The response rates for individual items in the emotion category ranged from 53 to 100% correct for adults and 29 to 100% correct for children. From the 20 emotion items, 15 items (3 items per categories) yielding the most accurate responses were selected, and were included in the final test. The mean accuracy scores for the final chosen items were as follows: Happy = 96% correct for adults, 95% correct for children; Sad= 98% correct for adults, 86% correct for children; Anger=74% correct for adults, 52% correct for children; Disgust=76% correct for both adults and children; Fear=73% correct for adults and 76% correct for children. Chance score for response was 20%. Consistent with prior studies on music and emotions, some emotions were more difficult to ascertain in musical examples than others (Juslin & Sloboda, 2010).

Pilot scores for the movement items: The mean scores for accuracy across all 20 movement items were 84.7% correct for the adults and 62.1% for the children. The response rates for individual items in the movement category ranged from 35% to 100% correct for

adults and 14% to 100% correct for children. From the 20 movement items, 12 items (3 items per categories) yielding the most accurate responses were selected for use in the final test. The mean scores for the final chosen items were as follows: Walk = 82% correct for adults, 85% correct for children; Run= 80% correct for adults, 85% correct for children; Skip=88% correct for adults, 90% correct for children; Climb=78% correct for adults and 43% correct for children. Because the scores on the category of Jump yielded mean scores of only 39% correct for adults and 33% correct for children, we considered these items to lack the level of accuracy desirable; thus, we chose to eliminate the category of jump from the pool of movement categories in the final test protocol.

Selection of response tokens for the test protocol: Consistent with many prior studies (including that of Heaton, Hudry, et al., 2008, which was successfully conducted with children with ASD), we used labeled photographs as response options on the computer screen. For the emotion items, a pool of 25 emotion photographs were selected from the International Affective Picture System (Lang, Bradley, Cuthbert, 2008; special permission was granted for use of the pictures by the developers of that database), which is based upon basic emotions conveyed through facial expression (based upon research of Ekman, Friesen, & Ellsworth, 1982). Twenty photographs of individuals engaged in the target movement categories of run, walk, skip, and climb were selected for the response options for the movement items.

The facial and movement photographs were reviewed for suitability by three professors with experience in language usage. Typically developing-normal hearing adults and children (not included in the final study) were pilot tested on a pool of 25 pictures of facial expression and 20 movements). Those photographs yielding the highest recognition scores for each of the emotions and movements were chosen for the computer interface in the final test protocol. The final items all had 100% accuracy in pilot testing.

The finalized PEMM required participants to listen to 27 short musical excerpts (3 items per category, approximately 10–15 seconds in length), with each excerpt conveying symbolic representation of an emotion or a movement. Each excerpt was presented only once, and in random order. The computer screen showed the pictures depicting either emotions or movements. Participants selected which emotion (5 AFC) or movement (4 AFC) best matched the musical excerpt. No feedback was offered on accuracy.

Additional test materials—Although both the CI and ASD groups have communication disorders, there are important etiological differences (e.g., peripheral vs. central disorder) and functional characteristics associated with these two groups. In addition, each group is characterized by variability on a host of influential factors. Therefore, to characterize the CI and ASD groups on factors relevant to communicative status, demographic and assessment data appropriate for each diagnostic category were gathered through charts or database information (in accordance with IRB requirements). Summary statistics for each group were described previously. These data were used primarily to verify membership in one of the three communicative status groups. When appropriate, these variables were also used in analyses to examine possible influences of these variables on the PEMM results.

To further characterize our participants with ASD, we mined three available measures of language level completed two to three years earlier (While these test values can change with age, the standard scores used in this study are considered to have good long-term stability). The *Peabody Picture Vocabulary Test – III (PPVT-III)* (Dunn & Dunn, 1997) is a standardized, norm-referenced measure of receptive vocabulary that employs a four-alternative-forced choice format. The mean of the normative sample is 100 with a standard deviation of 15. Using the norms appropriate for the participants' chronological ages, the mean of the sample of children with ASD was 109.33, the range was 82–141, and the standard deviation was 16.05. It is clear that these children had age-appropriate and, in some cases advanced, receptive vocabulary skills. As a group, they also performed well on the *Expressive Vocabulary Test-standard score (EVT)* (William, 2007), a standardized, norm-referenced test that measures expressive vocabulary by picture naming and provision of synonyms. The mean of the normative sample is 100 (SD = 15) while the mean of the participants in the ASD group was 94.08 (range=60–140; SD=20.51). Given that the range included scores as low as 60 (more than two standard deviations below the mean), we can conclude that some of the individuals in the ASD group did have deficits in expressive vocabulary development despite good performance by the group overall. The same can be said of their performance on The *Clinical Evaluation of Language Fundamentals (CELF-4)* (Kort, Schitterkatte, Compaan, 2008), a standardized, norm-reference measure of language comprehension and production at the word and sentence level. The mean of the normative sample is, again, 100 (SD = 15). The mean standard score earned by the participants with ASD was 99.54 (range=66–131, SD=18.78).

For the ASD group, relevant data included the following: chronological age, *PPVT-III*, *CELF-4*, and *EVT*. If the language assessment scores were not already available within the participant's file, those tests were administered at the time of testing on the PEMM. Because of constraints in time and resources related to testing and recruiting of a sufficient sample size, we were not able to gather data on prior musical training of the ASD group members. A table containing the mean and standard deviation of the variables tested for each group can be found in Table 2.

For the CI group, factors identified in prior research (e.g., Looi, et al., 2012) as influential in communication outcomes for CI users included chronological age, age of onset of hearing loss, age at implantation, device information (device type, signal processor, bi-lateral, unilateral use, or bimodal (CI+HA) use), and the *PPVT-III*. While several prior studies have failed to show a significant impact of prior musical instruction on several music perception skills of pediatric CI recipients (e.g., melody or timbre recognition) (e.g., See et al., 2012; Stordahl, 2002), we also examined relations between the PEMM and extent of musical instruction, which was available through the patient files.

Test protocol: In administering the PEMM, the test administrator presented the participants with written and verbal instructions regarding the test. Prior to testing, the test administrator confirmed that each participant had a clear understanding of the associations between the pictures and each emotion and movement; the emotion or movement labels were presented for the subject along with the appropriate picture. The test administer also asked if there were any questions. Then, the final instruction screen requested that the participant listen to

short songs and point to the emotion or movement that matched the music. Participants received a small token for their participation in the form of a toy or a gift card.

Statistical Analyses: To compare correct identification as a function of group by emotion or movement, we used a generalized linear mixed model (GLMM) in which the outcome variable (recognition of emotions or movements) was analyzed as correct or not correct in relation to the emotion or movement intended by the composer and performer of the excerpts. The GLMM included a logit link which is analogous to the common logistic regression analysis often used when the outcome variable is dichotomous. Additionally, the outcome variable responses were not all independent of each other, because each participant answered the emotions or movement stimuli three times. To account for the within-subject correlation introduced by the repeated measures design, a random intercept was included for participants, which used an unstructured covariance matrix. Group membership (CI, ASD, TD-NH), emotion (happy, sad, anger, fear, disgust) or movement (run, walk, skip, climb), chronological age, and an interaction between group and emotion or movement were included in the model as the independent variable fixed effects. This statistical model allowed us to characterize the relationship between the ability to correctly identify emotions and movements with our fixed effects of interest while accounting for repeated measurements.

To examine the relations between several individual characteristics and the dependent variables, Spearman correlations were computed for relevant individual characteristics. For variables that were not collected on all three groups, we tested whether their relationships with recognition were significantly different from zero. The ASD group was compared with TD-NH on chronological age and verbal age (measured by PPVT-III). Spearman correlations were also computed for recognition accuracy with PPVT-III for the CI group, PPVT-III for the ASD group, and CELF for the ASD group.

Note that an alpha level of 0.05 was used to determine significance in all analyses. This is consistent with many studies in the field of music therapy, including those focusing on communication disorders that manage type I error by setting the significance level to 0.05. However, the relationships between correct identification of emotion or movement and communication disorders are complex and possibly subtle, given that many different factors are at play regarding why someone chooses a particular emotion or movement for each musical excerpt. Thus, studies of this type, including the present analyses, should also be concerned about the level of type II error; lower type II error rates would allow more potential explanatory variables to be identified. The relationship between the type I and type II error rates is such that an increase in the probability of a type I error translates to a reduction in the probability of a type II error; using a strict level of significance in exploratory studies increases the likelihood of overlooking a potentially important association.

Results

Recognition of Emotions

Several research questions were related to accurate recognition of emotional content in musical excerpts: Does recognition accuracy for emotional content in musical excerpts differ as a function of communicative status (CI, ASD, TD-NH)? Are some emotions more easily identified by specific groups than others? Does accurate recognition of emotional content in music differ as a result of age or other relevant individual characteristics (e.g., language assessment scores, onset of hearing loss, age implanted)?

Regarding the first research question, recognition accuracy for emotional content in musical excerpts did differ as a function of communicative status. In averaging accuracy across all five emotions, interestingly, the ASD group had the highest overall mean of 80.8% correct. The TD-NH group was nearly as accurate at 79.4% correct. The CI group at 53.8% correct achieved the lowest accuracy for recognition of emotional content.

Results from the GLMM can be found in Table 3. Group ($p<0.0001$), emotion ($p<0.0001$), and their interactions ($p=.0002$) were all statistically significant predictors of correct response. Typically, when there is a significant interaction in a statistical model, the main effects are ignored in favor of the examining the interactions. However, if the interaction is mild but statistically significant, then averaging over the interaction effect and reporting the main effect is both meaningful and interpretable. In this case, the main effect for group was highly significant, even in the presence of a significant interaction. Therefore, we considered it important and relevant to comment on both. Figure 2 provides a helpful visual representation of these comparisons. Table 4, an error matrix, reveals patterns of confusion among the five emotions across all three groups. For example, this table indicates that the emotion of anger was identified accurately on 153 trials, or 59.3% of the time by all the groups, but it was confused with the emotion, disgust on 43 trials, or 16.67% of the time.

We begin by commenting on the interaction and then generalize the discussion to showcase why we see such a strong main effect. To understand the interaction, pairwise comparisons of recognition accuracy were examined conditional on group membership, beginning with the CI group. Analysis of the CI group revealed few significant differences between emotions, all of which were correctly identified between 46–65% of the time. The only significant differences (significance level of $<.05$) were between anger versus sad ($OR=2.17$) and disgust versus sad ($OR=2.06$). Essentially, this means that for the CI group, there were no significant differences in the ability to recognize happy, anger, disgust, and fear emotions. These four emotions were recognized at a similar level of accuracy.

Next, we examined the recognition patterns for the ASD group. The emotions were correctly identified between 59–94% of the time. For the ASD group, there were significant differences in accurate recognition of all pairs of emotions ($OR>2.31$), except for disgust vs. fear and happy vs. sad.

Finally, we examined the TD-NH group. All the emotions were correctly identified between 60–95% of the time. There were significant differences in accurate recognition of all pairs of emotions ($OR>2.55$), except for anger vs. disgust, fear vs. sad and happy vs. sad.

We then conducted pairwise comparisons of the three groups on recognition of emotions. Comparisons of the TD-NH versus ASD groups on each of the emotions yielded no significant differences between those two groups on recognition of any of the five emotions ($OR<1.93$). In other words, the ASD group had similar overall accuracy in recognition of emotions as the TD-NH group. However, pairwise comparisons revealed significant differences between the CI group and both the ASD and TD-NH groups. The ASD group was significantly more accurate than the CI group ($p<.02$, $OR>2.87$) for all of the emotions except anger ($p=.23$). The TD-NH group was significantly different from the CI group for all emotions ($p<.005$, $OR>2.86$) except for disgust ($p=.09$).

The reason for the highly significant main effect becomes clearer by examining Figure 2 where the CI group is shown to be considerably less accurate on all emotions. The main effect for group, of course, indicated overall differences by group membership (CI, ASD, TD-NH). More specifically, there were no significant differences between ASD and TD-NH for any of the emotions, therefore there was no overall difference between the TD-NH and ASD groups ($p=.97$) when averaging across emotions. The main effect must then be driven by the difference between the CI group with the other two groups, where overall, the CI group performed significantly less accurately than ASD ($p<0.0001$) and TD-NH ($p<0.0001$) groups when averaging across emotions. The interaction in the statistical model is significant because some emotions have a smaller difference (e.g., Disgust) than others (e.g., Happy).

Regarding the second question, main effect for emotion, some emotions were recognized more accurately than others across all groups. Averaging across groups, participants were most accurate in recognizing happy (89%) and sad (87%) (not a significant difference, Odds Ratio (OR)=1.21). An Odds Ratio might be explained within this context as follows: The odds of correctly identifying the emotion were 1.21 times higher for happy than they were for sad. Thus, happy was recognized accurately more often. However, both happy and sad were each significantly different (recognized accurately significantly more often) from all other emotions (p -values $< .005$, $OR>2.17$). On average, recognition of fear (76%) was significantly different (more accurate) from both disgust (63%) ($p=.0029$, $OR=1.87$) and anger (58%) ($p=.0001$, $OR=2.21$). There was not a significant difference between recognition of disgust and anger ($OR=1.18$).

Finally, we examined age and other relevant variables (see Table 2) in recognition of emotion. Relevant variables differed for all three groups, so we measured the association for each group separately. The mean age for the ASD group was slightly older than the TD-NH group in both chronological age and verbal age scores (according to the PPVT-III). However, chronological age was not a significant predictor of correctly identifying emotions ($p=.166$). Using Spearman correlation, the recognition accuracy for emotions was not significantly correlated with the PPVT-III for the CI group or the ASD group. However, recognition accuracy was significantly correlated with CELF for the ASD group ($p=.03$).

For the CI group, musical instruction was not significantly correlated with percent correct for emotions (Spearman $p=.1048$).

Movement Recognition

The following section addresses those research questions related to accurate recognition of movement cues in musical excerpts: Does accurate recognition of movement cues in musical excerpts differ as a function of communicative status (CI, ASD, TD-NH)? Are some movement cues more easily identified by specific groups than others? Does accuracy vary as a function of chronological age or other variables relevant to group membership and communication?

First, we compared recognition accuracy for movement as a function of group membership. The CI group demonstrated the least accurate recognition (46.8% correct). The TD-NH group and ASD group achieved very similar results on recognition of movements (75.2% and 72.2%, respectively).

Similar to the model used for emotions, we used a mixed effects logistic regression model to compare those percentages of correct identification and to compare each group by movement category. There was no significant interaction in this model ($p=0.7524$) and the following results are from the model that excludes the interaction term. We found that main effects for both group and movement were highly significant ($p<0.0001$). Chronological age was a significant predictor ($p=0.0308$) for accuracy in the model.

We next performed follow-up comparisons to determine which groups were different and for which movements there was significantly different recognition accuracy. Figure 3 illustrates the average percent correct for each movement as a function of group membership.

With regard to main effect for group, across all four movements, the ASD and TD-NH groups were not significantly different from each other ($p=.1352$, $OR=1.49$). However, ASD ($OR=2.80$) and TD-NH ($OR=4.17$) were significantly more accurate than the CI group ($p<0.0001$).

With regard to main effect for movement categories, (see figure 3) across groups, the category of climbing, was recognized with significantly less accuracy than the other three movement, ($p<.0001$, $OR>2.67$); accuracy for the movements, run, skip and walk, were not significantly different from each other. Table 5, an error matrix, indicates those movements that were confused with other movements across all three groups.

As noted previously, chronological age was a significant predictor ($p=.0308$) for accuracy in the regression model overall. There are many variables that were only collected on either the CI group or on the ASD group. Therefore, we targeted analyses on each group separately. For these analyses, we averaged across movements so that each participant only had one recognition score. Thus, a least squares regression analysis was performed with recognition as the dependent variable. For the CI group analysis, age at onset, age implanted, music background, and months of use were the relevant independent variables. None of these variables were significant predictors of movement recognition. For the ASD analysis,

ADOS, CELF, EVT, and PPVT-III were the relevant independent variables. Using Spearman correlations, recognition accuracy for movement was significantly correlated with standard PPVT-III score ($p=.02$). Recognition accuracy was not significantly correlated with ADOS, CELF, or EVT.

Discussion

The purpose of this study was to examine the extent to which children who have two different types of communication disorder of different etiological bases (severe hearing loss using CIs, and ASD) are able to recognize emotional or movement categories communicated through music. Some studies have suggested potential advantages of music as a therapeutic tool for goals related to either emotional expression or movement (Bonnel et al. 2003; Brownell, 2002; Heaton, 2003; Heaton et al, 1999; Heaton, Allen, et al., 2008; Hopyan, et al., 2011; Katagiri, 2009; Mottron, et al., 2000).. However, because different types of communication disorders may impact transmission, or decoding differently, it is important for music therapists to confirm the accessibility of musical cues that are salient to particular music therapy interventions with particular populations.

The results of this study indicate that children with ASD, who have deficits in social and emotional domains, but who are at the higher end of functioning on the ASD spectrum for behavioral, cognitive, and language skills, can effectively decode and recognize musical cues symbolizing emotions or movements at levels of accuracy comparable to a TD-NH group. Although the TD-NH participants were slightly younger than those in the ASD group, age was not a significant predictor of performance on the emotion items. These results are similar to several prior studies comparing children with ASD and TD children (e.g., Heaton, et al., 1999; Heaton, Allen, et al., 2008; Kastner& Crowder, 1990). These findings, however, cannot be generalized to other persons with ASD whose functional level is more limited, or who may have central processing deficits that result in degraded representation of psychophysical cues (O'Connor, 2012). In fact, the significant correlation between scores on standardized tests of language and performance on the emotion recognition suggests that further research examining lower-functioning individuals is needed. In addition, the specific response task in this study was category recognition for symbolic representation of either emotion or movement. Further research is necessary to determine whether accurate recognition can, in turn, contribute to enhanced functional applications (e.g., being able to relate emotions in music to relevant life events or socially appropriate responses; being able to produce appropriate physical movements in response to the symbolic representation).

In contrast with both the ASD and TD-NH group, the CI group was significantly less accurate in recognizing both emotional and movement cues. Thus, limited encoding and transmission of spectrally-complex cues, and thus, impaired perception of melody, harmony and timbre, was a significant impediment to this perceptual task. The results for the CI group confirm prior studies by Hopyan, et al. (2011, 2012), who found that pediatric CI users, while responding at above chance levels on recognition of happy or sad musical excerpts, were nevertheless significantly less accurate than NH peers. In the current study, similar results were also documented for three other emotions and musical excerpts representing

physical movements. It is interesting to note that for movement items, the CI group achieved very similar levels of accuracy on all of the movement categories except climbing (only slightly above chance levels), the only movement category for which melody was an important cue.

While the degraded representation of melody, harmony, and timbre transmitted by the CI is likely the key factor in less accurate recognition of conveyed emotions or movements for the group with hearing loss, it is also possible that differences in life experiences associated with hearing loss may be an influential factor, as was hypothesized in prior studies with deaf students or adults (Darrow, 2006; Darrow & Loomis, 1999). Although CI users who have embraced access to auditory communication differ in various ways from persons who have strong affiliation with Deaf culture (as was the case in the Darrow & Loomis study), nevertheless, CI users may, for a variety of reasons, have somewhat different life experiences with music than NH persons (Gfeller et al., 2008). Some of the children with CIs may have had less extensive exposure to music and music instruction (e.g., because of IEP decisions, Gfeller et al., 2012) in which the symbolic nature of music for conveying emotions or movement is presented. That being said, extent of musical experience (as measured through the musical background questionnaire) did not emerge as a significant predictor in the regression model, suggesting that lack of music instruction alone cannot explain these differences.

It is important to note once again that the population of persons who have significant hearing losses vary on a host of variables, including auditory profile, hearing device, and life experiences (e.g., music education). Thus, the findings with this pediatric CI group cannot be generalized to adults who are postlingually deaf (and thus grew up hearing music through a normal auditory mechanism), or to persons with more residual hearing who access more pitch and timbral cues through hearing aids. Further research is needed to better understand those individuals with differing hearing history (e.g., later onset of deafness), auditory profile (e.g., greater residual hearing), or hearing devices (e.g., conventional hearing aids).

An important difference between the two types of communication disorders (hearing loss and ASD) in this study is accessibility of salient psychophysical cues. For this ASD group, the peripheral auditory mechanism transmits musical structures normally, while the CIs encode temporal cues effectively but spectral cues (and thus pitch, melody, harmony and timbre) are poorly processed. Thus, the two groups had different access to musical structures (pitch, harmony, timbre, rhythm, tempo) known to support recognition of emotions or movement. For this ASD sample, their social communication deficits did not limit their recognition of the emotion and movement categories in the musical excerpts.

Within the group of emotion categories in this study, happy was the only emotion that would have been presented in major mode. Therefore, from a dimensional perspective, happy was the only category among the five emotions that was at the positive end of the continuum both on pleasantness (positive mood valence) as well as activation (energy). Sad, in contrast, was in a minor mode, and reflected both negative mood (unpleasantness) as well as low activation. The categories of happy and sad, therefore, may be considered the most straightforward and clearly contrasting emotional categories. Interestingly, the CI group had

similar levels of accuracy on fear and disgust as for happy and sad. This suggests that the limited access to modal cues may have limited the ability to differentiate happy and sad from other emotions. Although the CI group performed with significantly less accuracy on category recognition than the ASD and the TD-NH groups, it is, nevertheless, important to note that the children with CIs did perform above chance on several of emotions (consistent with results noted by Hopyan, et al., 2011) which is superior to emotion recognition (affective prosody) in spoken communication. This suggests that music therapy may still be a viable option for this population, particularly when the therapist takes into account those structural aspects more accurately perceived in selection of musical stimuli.

This study confirms prior studies that some emotions (e.g., happy and sad) are more easily conveyed through music than others (e.g., Gabrielsson & Juslin, 1996; Gabrielsson & Lindstrom, 2010; Juslin & Sloboda, 2010). More specifically, happy and sad were generally the emotions most readily recognized in this experiment. Prior studies indicate that even very young children (e.g., age 5) are able to accurately recognize happy and sad excerpts, while recognition of other emotions (e.g., anger, fear, disgust) tends to be more difficult; prior studies have shown improvement with increasing age (Dowling, 1999). In the present study, the majority of the children had reached age 7 or older, and chronological age was not a significant predictor for accurate identification of emotions. However, chronological age was a significant predictor for recognition of movements; thus younger children may require additional visual cues to support movement-oriented interventions.

In both the ASD and TD-NH groups, the categories of happy and sad were readily distinguished from each other and from the other three categories. In contrast, anger, fear, and disgust—all negative emotions, were more commonly confused with one another (see Table 2). All three of these emotions included dissonant harmonic material. If one considers emotion in a dimensional rather than categorical model emotional response, all three of these emotions share unpleasant (negative) valence for mood. In addition, both TD-NH and ASD groups tended to confuse disgust with sadness. These two emotions share factors of minor mode, slow tempo, and complex/dissonant harmonies. Finally, a proportion of both groups confused fear with anger, which together share sharp amplitude envelopes, narrow pitch variation, fast tempi, and complex/dissonant harmonies. Based on the structural similarities listed above, it is conceivable that excerpts containing these similarities could be confused, and thus additional cues (e.g., visual, contextual information) may be necessary to ensure clear communication.

Clinical Implications

In music therapy interventions regarding emotional or movement goals and objectives, it is important to recognize possible limitations in access to or interpretation of salient cues, particularly in cases of clients with communication disorders. Prior studies of children who use CIs indicate that temporal cues in music may be used more effectively than speech stimuli in exploring emotions (Hopyan et al., 2011), and temporal cues in music may be more accessible than emotional prosody cues in speech, thus making music a potentially beneficial mode for exploring emotions. That being said, spectral cues such as melody, mode, and timbre, which are poorly transmitted by the CI, appear to be quite important in

accurate recognition as well. With this population, music therapists may need to provide more accessible non-auditory cues (e.g., visual cues) in tasks requiring recognition of emotions or movement. Even though audibility of music is considerably greater through a CI than through hearing aids or without hearing devices, the degraded representation of pitch, melody, and timbre remains an impediment to effective communication of emotions or movements through music.

Despite the limitations that this CI group showed in decoding the musical cues, prior studies indicate that CI users can improve timbre recognition and succeed in paired associate learning. Thus, effective use of timbral cues may be improved through direct instruction and practice (Looi et al., 2012). As noted previously, some of the children with CIs may have had less extensive exposure to the concept of music as a symbol for emotions or movement because of curricular choices in their education. Thus, further study is needed to ascertain whether direct instruction can improve use of less easily perceived structural cues (pitch, timbre) in emotion or movement recognition.

Currently, music therapy is listed as an ‘emerging treatment’, by the National Autism Center’s (NAC) ‘National Standards Project (NSP)’ of 2009 (<http://nationalautismcenter.org/nsprereports.php>). These results provide some support for the use of music as a therapeutic tool for this population, particularly those persons with similar functional capabilities. While many children with autism may be able to understand which emotions are conveyed by music, another question arises: whether children with ASD can use music to convey their own emotions more effectively. It cannot be presumed that functional skills in emotional expression or regulation naturally follow accurate recognition. Nevertheless, confirmation that this group can recognize emotions accurately is an important step in determining the appropriateness of music in interventions geared toward emotional functioning. Because verbal communication is often difficult for persons with ASD, perhaps expressive communication through music would be an area of further study. Further studies are needed to examine therapeutic applications related to emotional recognition, expression, and regulation. Similarly, further study is required to ascertain whether recognition of symbolic expression of movement can transfer to production of physical movements.

In conclusion, music is a powerful form of communication with many therapeutic applications. However, in serving clients whose disabilities include communication deficits, it is especially important to consider the unique characteristics of a given communication disorder and how it may reduce or alter encoding, transmission or decoding of structural features and symbolic representation in music essential to effective communication. This study provides insights regarding two types of communication disorders with differing etiologies and deficits, and suggests possible uses as well as needed accommodations in relation to therapy interventions addressing emotions or movement.

Acknowledgments

The authors would like to thank all those who took part in this study and Nicole Studt for assistance in organizing data for appropriate selection of participants.

This study was supported by grant 2 P50 DC00242, RO1 DC012082-10, and 2 RO1 DC003698-06 from the NIDCD, NIH; grant RR00059 from the General Clinical Research Centers Program, NCRR, NIH; and the Iowa Lions Foundation.

References

- Adamek, MS.; Thaut, MH.; Furman, AG. Individuals with autism and autism spectrum disorders (ASD). In: Davis, WB.; Gfeller, KE.; Thaut, MH., editors. *An introduction to music therapy: Theory and Practice*. 3. Silver Spring, MD: American Music Therapy Association; 2008. p. 117-142.
- Allen R, Heaton P. Autism, music, and the therapeutic potential of music in alexithymia. *Music Perception: An Interdisciplinary Journal*. 2010; 27:251–261.
- American Music Therapy Association. *Standards of Clinical Practice*. AMTA; 8455 Colesville Road, Suite 1000, Silver Spring, Maryland 20910: 2013. Retrieved June 5, 2014 from: <http://www.musictherapy.org/about/standards/>
- American Psychiatric Association. *Diagnostic and statistical manual of mental disorders*. 5. Arlington, VA: American Psychiatric Publishing; 2013.
- Bal E, Harden E, Lamb D, Van Hecke AV, Denver JW, Porges SW. Emotional recognition in children with autism spectrum disorders: Relations to eye gaze and autonomic state. *Journal of Autism and Developmental Disorders*. 2010; 40:358–370. [PubMed: 19885725]
- Balkwill LL, Thompson WF. A cross-cultural investigation of the perception of emotion in music: Psychophysical and cultural cues. *Music Perception: An Interdisciplinary Journal*. 1999; 17(1):43–64.
- Baron-Cohen S, Ring HA, Bullmore ET, Wheelwright S, Ashwin C, Williams SC. The amygdala theory of autism. *Neuroscience & Biobehavioral Reviews*. 2000; 24(3):355–364. [PubMed: 10781695]
- Baron-Cohen S, Golan O, Wheelwright S, Granader Y, Hill J. Emotion word comprehension from 4 to 16 years old: A developmental survey. *Frontiers in evolutionary neuroscience*. 2010; 2:109. [PubMed: 21151378]
- Bauminger N, Kasari C. Loneliness and friendship in high functioning children with autism. *Child Development*. 2000; 71(2):447–456. [PubMed: 10834476]
- Bhatara A, Quintin EM, Levy B, Bellugi U, Fombonne E, Levitin DJ. Perception of emotion in musical performance in adolescents with autism spectrum disorders. *Autism Research*. 2010; 3:214–225. [PubMed: 20717952]
- Bonnell A, Mottron L, Peretz I, Trudel M, Gallum E, Bonnell A. Enhanced pitch sensitivity in individuals with autism: A signal detection analysis. *Journal of Cognitive Neuroscience*. 2003; 15:206–235.
- Boso M, Emanuele E, Minazzi V, Abbamonte M, Politi P. Effect of long-term interactive music therapy on behavior profile and musical skills in young adults with severe autism. *The Journal of Alternative and Complementary Medicine*. 2007; 13(7):709–712. [PubMed: 17931062]
- Brownell MD. Musically adapted social stories to modify behaviors in students with autism: Four case studies. *Journal of Music Therapy*. 2002; 39(2):117–144. [PubMed: 12213082]
- Darrow AA. The perception of emotion in music by deaf and hard-of-hearing children. *Journal of Music Therapy*. 2006; 43(1):2–15. [PubMed: 16671835]
- Darrow AA, Loomis D. Music and deaf culture: Images from the media and their interpretation by deaf and hearing students. *Journal of Music Therapy*. 1999; 44:57–73. [PubMed: 17419664]
- Dowling, WJ. The development of music perception and cognition. In: Deutsch, D., editor. *Psychology of music*. 2. NY: Academic Press; 1999. p. 603-626.
- Dunn, LM.; Dunn, LM. *The Peabody Picture Vocabulary Test*. 3. Circle Pines, MN: American Guidance Service; 1997.
- Ekman, P.; Friesen, WV.; Ellsworth, P. Research foundations. In: Ekman, P., editor. *Emotion in the human face*. 2. Cambridge: Cambridge University Press; 1982.
- Gabrielsson A, Juslin PN. Emotional expression in music performance: Between the performer's intention and the listener's experience. *Psychology of Music*. 1996; 24:68–91.

- Gabrielsson, A.; Lindstrom, E. The role of structure in the musical expression of emotion. *Handbook of music and emotion: Theory, research, applications*. Oxford: Oxford University Press; 2010.
- Gfeller, K. Music: A human phenomenon and therapeutic tool. In: Davis, WB.; Gfeller, KE.; Thaut, MH., editors. *An Introduction to Music Therapy Theory and Practice*. American Music Therapy Association, Inc; Silver Spring, Maryland: 2008. p. 41-75.
- Gfeller, K. Music as communication. In: Bruscia, K., editor. *Readings on Music Therapy Theory* [E-book], Reading 17. Gilsum NH: Barcelona Publishers; 2012a. www.barcelonapublishers.com
- Gfeller, K. The Function of Aesthetic Stimuli in the Therapeutic Process. In: Bruscia, K., editor. *Readings on Music Therapy Theory* [E-book], Reading 19. Gilsum NH: Barcelona Publishers; 2012b. www.barcelonapublishers.com
- Gfeller K, Oleson J, Knuston J, Breheny P, Driscoll V, Olszewski C. Multivariate predictors of music perception and appraisal by adult cochlear implant users. *Journal of the American Academy of Audiology*. 2008; 19:120–134. [PubMed: 18669126]
- Gfeller K, Driscoll V, Kenworthy M, Van Voorst T. Music therapy for preschool cochlear implant recipients. *Music Therapy Perspectives*. 2011; 29:39–49. [PubMed: 23904691]
- Gfeller K, Driscoll V, Smith RS, Scheperle C. The music experiences and attitudes of a first cohort of prelingually deaf adolescents and young adult CI recipients. *Seminars in Hearing*. 2012; 33:346–360. [PubMed: 23565029]
- Gfeller, KE.; Darrow, AA. Music therapy in the treatment of sensory disorders. In: Davis, WB.; Gfeller, KE.; Thaut, MH., editors. *An Introduction to Music Therapy Theory and Practice*. American Music Therapy Association, Inc; Silver Spring, Maryland: 2008. p. 365-404.
- Gillam, RB.; Marquardt, TP.; Martin, FN. *Communication sciences and disorders: From science to clinical practice*. San Diego, CA: Singular Publishing Group; 2000. p. 25-61.
- Gold C, Wigram T, Elefant C. Music therapy for autistic spectrum disorder. *The Cochrane Database of Systematic Reviews* 2006. 2006; (2)10.1002/14651858.CD004381.pub2
- Guaستا AJ, Einfeld SL, Gray KM, Rineart NJ, Tonge BJ, Lambert TJ, Hickie IB. Intranasal oxytocin improves emotion recognition for youth with autism spectrum disorders. *Biological Psychiatry*. 2010; 67(7):682–694.
- Heaton P. Pitch memory, labeling and disembedding in autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*. 2003; 8(3):339–353.
- Heaton P, Allen R, Williams K, Cummins O, Happe F. Do social and cognitive deficits curtail musical understanding? Evidence from autism and Down syndrome. *The British Psychological Society*. 2008; 26:171–182.
- Heaton P, Hermelin B, Pring L. Can children with autistic spectrum disorders perceive affect in music? An experimental investigation. *Psychological Medicine*. 1999; 29:1405–1410. [PubMed: 10616946]
- Heaton P, Hudry K, Ludlow A, Hill E. Superior discrimination of speech pitch and its relationship to verbal ability in autism spectrum disorders. *Cognitive Neuropsychology*. 2008; 25(6):771–782. [PubMed: 18720290]
- Hopyan T, Gordon KA, Papsin BC. Identifying emotions in music through electrical hearing in deaf children using cochlear implants. *Cochlear Implants International*. 2011; 12:21–26. [PubMed: 21756455]
- Hopyan T, Peretz I, Chan LP, Papsin BC, Gordon KA. Children using cochlear implants capitalize on acoustical hearing for music perception. *Frontiers in psychology*. 2012; 3
- Hsiao F, Gfeller K. Music Perception of Cochlear Implant Recipients With Implications for Music Instruction A Review of the Literature. Update: Applications of Research in Music Education. 2012; 30(2):5–10.
- Juslin PN. Cue utilization in communication of emotion in music performance: Relating performance to perception. *Journal of Experimental Psychology: Human Perception and Performance*. 2000; 26:1797–1813. [PubMed: 11129375]
- Juslin, PN.; Sloboda, JA., editors. *Handbook of music and emotion: Theory, research, applications*. Oxford University Press; 2010.

- Juslin, PN.; Timmers, R. Expression and communication of emotion in music performance. In: Juslin, PN.; Sloboda, JA., editors. *Handbook of Music and Emotion*. Oxford: Oxford University Press; 2010. p. 453-489.
- Kaplan RS. An analysis of music therapy program goals and outcomes for clients with diagnoses on the autism spectrum. *Journal of Music Therapy*. 2005; 42:2–19. [PubMed: 15839730]
- Kastner MP, Crowder RG. Perception of the major/minor distinction: IV. Emotional connotations in young children. *Music Perception*. 1990; 8:189–201.
- Katagiri J. The effect of background music and song texts on the emotional understanding of children with autism. *Journal of Music Therapy*. 2009; 46:15–31. [PubMed: 19256729]
- Kern P, River NR, Chandler A, Humpal M. Music therapy services for individuals with autism spectrum disorder: A survey of clinical practices and training needs. *Journal of Music Therapy*. 2013; 50:274–303. [PubMed: 25014668]
- Kort, W.; Schittekatte, M.; Compaan, E., editors. *CELF-4-NL: Clinical Evaluation of Language Fundamentals*. Amsterdam: Pearson Assessment and Information B.V; 2008.
- Kwoun S. An examination of cue redundancy theory in cross-cultural decoding of emotions in music. *Journal of Music Therapy*. 2009; 46(3):217–237. [PubMed: 19757877]
- Lang, PJ.; Bradley, MM.; Cuthbert, BN. Technical Report A-8. University of Florida; Gainesville, FL: 2008. International affective picture system (IAPS): Affective ratings of pictures and instruction manual.
- Limb CJ, Roy AT. Technological, Biological, and Acoustical Constraints to Music Perception in Cochlear Implant Users. *Hearing research*. 2014; 308:13–26. [PubMed: 23665130]
- Looi V, Gfeller K, Driscoll V. Music appreciation and training for cochlear implant recipients: A review. *Seminars in hearing*. 2012 Nov;33:307–334. [PubMed: 23459244]
- Lord, C.; Rutter, M.; DiLavore, PC.; Risi, S. *Autism Diagnostic Observation Schedule Manual*. Los Angeles: Western Psychological Services; 2008.
- McCann J, Peppe S, Gibbon FE, O'Hare A, Rutherford M. Prosody and its relationship to language in school-aged children with high-functioning autism. *International Journal of Language and Communication Disorders*. 2007; 42:682–702. [PubMed: 17885824]
- Molnar-Szakacs I, Wang WJ, Laugeson EA, Overy K, Wu WL, Piggot J. Autism, emotion recognition and the mirror neuron system: The case of music. *McGill Journal of Medicine Focus*. 2009; 12:87–98.
- Mottron L, Peretz I, Menard E. Local and global processing of music in high-functioning persons with autism: Beyond central coherence? *The Journal of Child Psychology and Psychiatry*. 2000; 41:1057–1065.
- National Autism Center. National Standards Project. 2009. Retrieved September 10, 2011, from <http://nationalautismcenter.org/nsp/reports.php>
- National Research Council. *Educating children with autism*. Washington, DC: National Academy Press; 2001.
- Niedenthal, PM.; Kruth-Gruber, S.; Ric, F. *Principles of Social Psychology series*. New York: Psychology Press; 2006. *The Psychology of Emotion: Interpersonal Experiential, and Cognitive Approaches*; p. 1-77.
- North AC, Hargreaves DJ, O'Neill SA. The importance of music to adolescents. *British Journal of Educational Psychology*. 2000; 70:255–272. [PubMed: 10900782]
- O'Connor K. Auditory processing in autism spectrum disorder: a review. *Neuroscience and Biobehavioral Reviews*. 2012; 36:836–854. [PubMed: 22155284]
- O'Riordan M, Passetti F. Discrimination in autism within different sensory modalities. *Journal of Autism and Developmental Disorders*. 2006; 36:665–675. [PubMed: 16639532]
- Owens, RE, Jr. *Language development: An introduction*. 5. Boston: Allyn and Bacon; 2001.
- Patel, AD. *Music, language, and the brain*. Oxford University Press; USA: 2010.
- Rutherford MD, McIntosh DN. Rules versus prototype matching: Strategies of perception of emotional facial expressions in the autism spectrum. *Journal of Autism and Developmental Disorders*. 2007; 37:187–196. [PubMed: 16897386]

- Saarikallio, S. Jyväskylä Studies in Humanities. University of Jyväskylä; 2007. Music as mood regulation in adolescence; p. 67
- See RL, Driscoll VD, Gfeller K, Kliethermes S, Oleson J. Speech intonation and melodic contour recognition in children with cochlear implants and with normal hearing. *Otology& Neurotology* (34). (3):490–498.
- Silani G, Bird G, Brindley R, Singer T, Frith C, Frith U. Levels of emotional awareness and autism: an fMRI study. *Social Neuroscience*. 2008; 3:97–112. [PubMed: 18633852]
- Stordahl J. Song recognition and appraisal: A comparison of children who use cochlear implants and normally hearing children. *Journal of Music Therapy*. 2002; 39:2–19. [PubMed: 12015808]
- Thaut, MH. *Rhythm, Music, and the Brain*. NY: Routledge; 2005. p. 1-59.
- Thaut, MH.; Thaut, C.; LaGasse, B. Music therapy in neurologic rehabilitation. In: Davis, WB.; Gfeller, KE.; Thaut, MH., editors. *An Introduction to Music Therapy Theory and Practice*. American Music Therapy Association, Inc; Silver Spring, Maryland: 2008. p. 261-304.
- Volker MA, Lopata C, Smith DA, Thomeer ML. Facial encoding of children with high-functioning autism spectrum disorders. *Focus on Autism and Other Developmental Disabilities*. 2009; 24(4): 195–204.
- William, K. *Expressive Vocabulary Test 2*. Circle Pines, MN: American Guidance Service; 2007.

Figure 1.
Examples of Musical Excerpts used in Test

Figure 2.
Recognition for Emotion by Group means and Standard Error Bars

Figure 3.
Recognition for Movement by Group Means and Standard Error Bars

Table 1

Musical Structures for Emotional Expression

	MUSICAL STRUCTURE FOR EMOTIONAL EXPRESSION	
EMOTION	RESEARCH LITERATURE	RESEARCH STUDY
Happy (glad, joyful)	<ul style="list-style-type: none"> • Sharp amplitude envelope • High pitched • Wide pitch range and variation • Ascending melody • Major mode * • Regular/smooth rhythm * • Fast tempo * • Tonal * • Simple/consonant harmony 	<ul style="list-style-type: none"> • Tempo <ul style="list-style-type: none"> – 111 bpm • Mode <ul style="list-style-type: none"> – Major • Articulatory gestures <ul style="list-style-type: none"> – Moderate vibrato, lilting, dotted rhythms
Sad	<ul style="list-style-type: none"> • Legato * • Low pitched • Narrow pitch range • Descending melody • Minor mode * • Slow tempo * • Chromatic • Complex/dissonant harmony * 	<ul style="list-style-type: none"> • Tempo <ul style="list-style-type: none"> – 90 bpm • Mode <ul style="list-style-type: none"> – Minor • Articulatory gestures <ul style="list-style-type: none"> – Legato, slow vibrato
Anger (agitation)	<ul style="list-style-type: none"> • Sharp amplitude envelope • Staccato * • Minor mode * • Narrow pitch variation • Complex rhythm • Fast tempo * • Atonal/chromatic * • Complex/dissonant harmony * 	<ul style="list-style-type: none"> • Tempo <ul style="list-style-type: none"> – 197 bpm • Mode <ul style="list-style-type: none"> – Dissonance, atonal • Articulatory gestures <ul style="list-style-type: none"> – Agogic attacks, double stops, marcato, accents, fast vibrato
Disgust (unpleasantness)	<ul style="list-style-type: none"> • Minor mode * • Narrow pitch variation • Slow tempo * • Complex/dissonant harmony * 	<ul style="list-style-type: none"> • Tempo <ul style="list-style-type: none"> – 62 bpm • Mode <ul style="list-style-type: none"> – Complex harmony, atonal • Articulatory gestures <ul style="list-style-type: none"> – Tempo fluctuations, finger slides
Fear	<ul style="list-style-type: none"> • Sharp amplitude envelope • Wide pitch range 	<ul style="list-style-type: none"> • Tempo <ul style="list-style-type: none"> – 100 bpm

	MUSICAL STRUCTURE FOR EMOTIONAL EXPRESSION	
EMOTION	RESEARCH LITERATURE	RESEARCH STUDY
	<ul style="list-style-type: none"> Narrow pitch variation Fast tempo* Complex/dissonant harmony* 	<ul style="list-style-type: none"> Mode <ul style="list-style-type: none"> – Minor Articulatory gestures <ul style="list-style-type: none"> – Tremolo, double stops, dissonance

* Musical characteristics used in research study excerpts.

Table 2

Variables tested for each group.

Group	Variables	Means (SD)
ASD	Age (years)	14.25 (2.21)
	PPVT	109.33 (16.05)
	ADOS	13.88 (4.00)
	EVT	94.08 (20.51)
	CELF	99.54 (18.78)
CI	Age (years)	12.38 (3.14)
	Age onset	6.72 (16.45)
	Age at implant (months)	41.27 (30.08)
	Months of use	105.49 (37.88)
	PPVT	81.6 (16.92)
	Music Instruction (units)	6.19 (3.62)
TD-NH	Age (years)	11.06 (2.84)
	PPVT	115.10 (9.13)

* Sex was collected on all groups, CI device information on the CI group, for descriptive purposes only

Table 3

Results from GLMM for Emotion and Movements

Emotions						
Variable	Difference	Standard Error	Test Statistic	p-value	Odds Ratio	
Label			F=24.20	<0.0001		
ASD vs CI	1.55	0.29	t=5.24	<0.0001	4.72	
TD-NH vs ASD	0.01	0.32	t=0.04	0.9693	1.01	
TD-NH vs CI	1.56	0.26	t=6.10	<0.0001	4.78	
Emotion			F=18.04	<0.0001		
Disgust vs Anger	0.17	0.19	t=0.87	0.3830	1.18	
Fear vs Anger	0.79	0.21	t=3.87	0.0001	2.21	
Happy vs Anger	1.76	0.28	t=6.28	<0.0001	5.81	
Sad vs Anger	1.57	0.26	t=6.11	<0.0001	4.81	
Fear vs Disgust	0.63	0.21	t=2.98	0.0029	1.87	
Happy vs Disgust	1.59	0.28	t=5.62	<0.0001	4.90	
Sad vs Disgust	1.40	0.26	t=5.39	<0.0001	4.05	
Happy vs Fear	0.96	0.29	t=3.32	0.0009	2.62	
Sad vs Fear	0.77	0.27	t=2.89	0.0039	2.17	
Happy vs Sad	0.19	0.33	t=0.58	0.5647	1.21	
Label * Emotion			F=3.80	0.0002		
ASD; Disgust vs Anger	0.84	0.38	t=2.20	0.0278	2.31	
ASD; Fear vs Anger	1.01	0.39	t=2.59	0.0098	2.75	
ASD; Happy vs Anger	2.58	0.58	t=4.44	<0.0001	13.16	
ASD; Sad vs Anger	2.58	0.58	t=4.44	<0.0001	13.16	
ASD; Fear vs Disgust	0.17	0.42	t=0.41	0.6787	1.19	
ASD; Happy vs Disgust	1.74	0.60	t=2.92	0.0036	5.71	
ASD; Sad vs Disgust	1.74	0.60	t=2.92	0.0036	5.71	
ASD; Happy vs Fear	1.57	0.60	t=2.61	0.0093	4.81	
ASD; Sad vs Fear	1.57	0.60	t=2.61	0.0093	4.81	
ASD; Happy vs Sad	0.00	0.74	t=0.00	0.9999	1.00	

Emotions					
Variable	Difference	Standard Error	Test Statistic	p-value	Odds Ratio
CI; Disgust vs Anger	0.05	0.33	t=0.17	0.8688	1.06
CI; Fear vs Anger	0.44	0.33	t=1.32	0.1883	1.55
CI; Happy vs Anger	0.38	0.33	t=1.15	0.2495	1.46
CI; Sad vs Anger	0.78	0.34	t=2.30	0.0214	2.17
CI; Fear vs Disgust	0.38	0.33	t=1.15	0.2492	1.46
CI; Happy vs Disgust	0.33	0.33	t=0.99	0.3233	1.39
CI; Sad vs Disgust	0.72	0.34	t=2.14	0.0322	2.06
CI; Fear vs Happy	0.06	0.33	t=0.17	0.8683	1.06
CI; Sad vs Fear	0.34	0.34	t=1.01	0.3138	1.40
CI; Sad vs Happy	0.40	0.34	t=1.17	0.2414	1.48
TD-NH; Anger vs Disgust	0.38	0.29	t=1.31	0.1903	1.47
TD-NH; Fear vs Anger	0.94	0.34	t=2.74	0.0063	2.55
TD-NH; Happy vs Anger	2.31	0.51	t=4.55	<0.0001	10.10
TD-NH; Sad vs Anger	1.35	0.38	t=3.59	0.0003	3.86
TD-NH; Fear vs Disgust	1.32	0.34	t=3.93	<0.0001	3.74
TD-NH; Happy vs Disgust	2.70	0.50	t=5.35	<0.0001	14.93
TD-NH; Sad vs Disgust	1.73	0.37	t=4.68	<0.0001	5.68
TD-NH; Happy vs Fear	1.37	0.53	t=2.58	0.0100	3.95
TD-NH; Sad vs Fear	0.41	0.41	t=1.01	0.3140	1.51
TD-NH; Happy vs Sad	0.96	0.56	t=1.73	0.0834	2.62
Age			F=1.92	0.1661	

Movements					
Variable	Difference	Standard Error	Test Statistic	p-value	Odds Ratio
Label			F=22.00	<0.0001	
ASD vs CI	1.03	0.24	t=4.21	<0.0001	2.80
TD-NH vs ASD	0.40	0.25	t=1.57	0.1169	1.49
TD-NH vs CI	1.42	0.22	t=6.41	<0.0001	4.17
Movement			F=12.42	<0.0001	

Movements		Difference	Standard Error	Test Statistic	p-value	Odds Ratio
Variable						
Run vs Climb		0.98	0.20	t=5.00	<0.0001	2.67
Skip vs Climb		0.90	0.20	t=4.61	<0.0001	2.46
Walk vs Climb		0.98	0.20	t=5.00	<0.0001	2.67
Run vs Skip		0.08	0.20	t=0.41	0.6839	1.09
Run vs Walk		0.00	0.21	t=0.00	0.9999	1.00
Walk vs Skip		0.08	0.20	t=0.41	0.6839	1.09
Age				F=4.69	0.0306	

Table 4

Error Matrix for Emotions

Emotion		Table of Emotion by Observed					
		Observed				Total	
Frequency	Anger	Anger	Disgust	Fear	Happy	Sad	Total
Row Percentage		153	43	45	16	1	258
		59.30	16.67	17.44	6.20	0.39	
	Disgust	10	157	27	4	60	258
		3.88	60.85	10.47	1.55	23.26	
	Fear	28	28	192	0	10	258
		10.85	10.85	74.42	0.00	3.88	
	Happy	12	15	9	214	8	258
		4.65	5.81	3.49	82.95	3.10	
	Sad	4	10	18	11	215	258
		1.55	3.88	6.98	4.26	83.33	
	Total	207	253	291	245	294	1290