The effect of music on auditory perception in cochlear-implant users and normal-hearing listeners

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Chapter 9

The effect of musical training and music therapy on speech and music perception in cochlear-implant users

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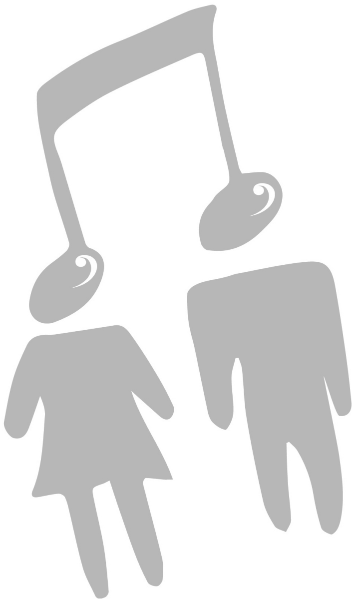

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ABSTRACT

Music is reported to be the second most important acoustical stimulus by cochlear-implant (CI) users. Yet music is not well-perceived, nor enjoyed by CI users. Previously, normal-hearing musicians have been shown to have better speech perception in noise, pitch perception in speech and music, as well as a better working memory and enhanced neural encoding of speech, compared to non-musicians. Based on these findings, we hypothesize that music therapy and musical training may have a positive effect on speech and music perception in CI users.

Three groups of CI users were recruited for six weeks of musical training, music therapy and non-musical training for 2 hours per week. These different types of training were selected to vary in their level of experimental control and human interaction. Musical training involved individual computerized training with melodic contour identification and instrument recognition. Music therapy involved group exercises involving rhythm, musical speech, singing, emotion identification and improvisation. Non-musical training involved group activities involving writing, cooking, and woodworking. Before and after the training, all participants were tested behaviorally for speech and music-related tasks (emotion identification, melodic contour identification). Quality of life was quantified using the Nijmegen Cochlear Implant Questionnaire.

In general, training effects were observed within domain (from musical training to better melodic contour identification), with little transfer across domains (no effect of any of the three training approaches on speech perception, but an effect of music therapy on emotion identification). The music therapy group also reported enhanced subjective perceptual skills. None of the training methods showed an effect on quality of life.

Given the short duration of training, it is promising that music therapy already showed a cross-domain positive effect on emotion identification, along with subjective reports of benefit. It is possible that the interactive nature of music therapy was useful; however, further research is needed with more participants and with longer durations of training.

INTRODUCTION

Recent research has shown that normal-hearing (NH) musicians have certain benefits for the perception of auditory signals. For example, musicians have been shown to have a better perception of pitch and a better ability to detect pitch changes in foreign languages (Marques et al. 2007; Besson et al. 2007). This indicates that musical training and thus being a musician can create benefits for music related auditory perception. Moreover, musicians, even though the results of the studies are more ambivalent, have also been shown to have a better perception of speech, both in quiet and in noise (Ruggles, Freyman, and Oxenham 2014; Parbery-Clark et al. 2009; Boebinger et al. 2015; Swaminathan et al. 2015; Zendel and Alain 2013). This indicates that musical training could also create a benefit for speech perception, a possible positive transfer or training effect of music on speech.

These advantages in auditory perception from musical training make musicians into a very interesting research group, as they can serve as a model for neural plasticity of auditory perception (Herholz and Zatorre 2012). Furthermore, the neural plasticity of musical training could be interesting for other groups of listeners, so not only for normal hearing (NH) listeners, but also for hearing deprived persons, such as cochlear implant (CI) users (Fuller et al. 2014b; Fuller et al. 2014a). This study will focus on the possible positive effects of music related training on auditory perception and the quality of life in CI users.

Music in CI users

Music is the second most important auditory signal for CI users, but yet not well perceived or enjoyed (Drennan and Rubinstein 2008; Gfeller et al. 2000; Philips et al. 2012; Fuller et al. under revision). The perception of music and its basic elements (rhythm, pitch, melody and timbre) is less exact in CI users compared to NH listeners. This difference in perception is partially due to the difference between acoustic and electric hearing, thus factors related to the CI itself. Due to the limited amount of simulation sites in the cochlea the perceived tonotopy is imprecise. Furthermore, spectral and temporal limitations of the device caused by the speech processing strategies that only retain the slow temporal envelope cause the perception of three of four of the basic elements of music, pitch, melody and timbre to be perceived poorer in CI users in comparison to NH listeners (NH) (see for a review: McDermott 2004; Galvin, Fu, and Nogaki 2007; Gfeller et al. 2007; Gfeller et al. 2002; Kong et al. 2009; Looi and She 2010; Looi, Gfeller, and Driscoll 2012; Limb and Roy 2014). Only rhythm is perceived with almost similar accuracy in CI users as in NH listeners (Gfeller et al. 2007; Kong et al. 2004).

Next to the limitations caused by the device – implant-related limitations – CI users have suffered from changes in the auditory nervous system, posing patient-related limitations as well (Limb and Roy (2014) for a review). For example, most post-lingually deafened implantees have a possibly deprived peripheral and/or central auditory pathway, caused by different etiologies, different survival of spiral ganglia or caused by changes in cognitive elements, such as can develop after a long period of profound deafness. The patient- and implant-related factors together cause a degraded perception of the elements of music (Başkent and Gaudrain 2016). These factors not only cause difficulties in music perception, but also affect the perception of pitch. A deprived perception of pitch causes difficulties in areas such as speech-on-speech perception, the identification of vocal emotions or the gender of a talker, as well as on the perception of more complex and more pitch-related signals such as melodies and the perception and appreciation of music itself (Philips et al. 2012; McDermott 2004; Galvin, Fu, and Nogaki 2007; Gfeller et al. 2007; Looi, Gfeller, and Driscoll 2012; Wright and Uchanski 2012; Gilbers et al. 2015; Fuller et al. 2014c; Xin, Fu, and Galvin 2007).

Research using musical training could therefore serve several purposes in CI users: first, it could give us insight in the perception of music in CI users; second, it could be a fun way to train and enhance the music and possibly speech perception; and third, it could serve as a model for the enhancement of the neural plasticity of CI users for auditory signals.

Musician effect in CI

Because of the limitations of both the device and the patient for music perception, it is unclear if the ‘musician effect’, the possible positive effect of musical training on speech perception, would persist and/or exist in CI users. The effect of musical training or rehabilitation has been less well explored in CI users. Thus far, focused music training in CI users shows that melodic contour processing, timbre recognition and complex melody tasks recognition can be improved (Oba, Fu, and Galvin 2011; Gfeller et al. 2002; Looi, Gfeller, and Driscoll 2012). All these studies focus on the within domain neural plasticity, i.e. if you train music this only affects the perception of music itself. To see whether the musician effect also exists in auditory deprived situations such as with electrical hearing in CI users, Fuller et al. (2014b) recently studied NH musicians and non-musicians listening to CI simulated stimuli, both speech and music. The results showed a small, transfer effect of musical training for word identification in noise. No effect for the perception of sentences both in quiet and in noise was found. A musician effect, however, was shown for the identification of emotions, as well as for the identification of melodic contours. It was suggested that the musician effect in this study could be based on a better perception of pitch. Still the question remains whether the musician effect persists in CI users. Thus far only two studies investigated the effect of musical training on speech perception in CI users. A pilot study with two CI users showed a small effect of purely instrumental, melodic contour identification training on speech in noise reception thresholds in one CI user and an improvement of prosody in words perception in the other CI user (Patel 2014). A second study by Lo et al. (2015) showed an effect of two melodic contour training programs on speech perception in 16 CI users and 12

NH listeners. One group was trained with different semitone interval sizes, the other with the duration of the notes. Both groups were trained for six weeks and tested before and after for sentences in four talker babble noise perception, consonant discrimination and prosody identification. Results indicated a small effect of both training methods in CI users on consonant identification and prosody identification, no effect on sentences in babble was shown. The results from all these studies indicate possibilities for cross-domain training effect of music on speech in CI users. Nevertheless all these studies lack a control group to see whether no intervention could give a better perception as well.

Methods of training

Conventional auditory training seems to be effective in CI users. Bottom up auditory training has been shown to improve the auditory perception of the stimulus trained with, for example improvement of speech in noise recognition by training speech in noise (Fu and Galvin 2008; Ingvalson et al. 2013). Which method is best for training music perception and enjoyment, and investigating the transfer effect on speech is unclear.

In this study three different types of training and groups will be exploited. First, an individualized, computerized musical training using melodic contour identification; second, a group-wise music therapy and third, a control group that receives group-wise training that is not related to music or auditory perception.

The first group, the musical training group received training based on an individual, computerized training. Computer based training, which allows for an easy, individual training for large numbers of trials, has been used in different CI training studies, regarding different topics of perception, including as described above music perception (see: Galvin, Fu, and Nogaki 2007; Başkent et al. 2016; Benard and Başkent 2013; Fu, Chinchilla, and Galvin 2004; Fu, Nogaki, and Galvin III 2005; Galvin et al. 2012; Stacey et al. 2010; Loebach and Pisoni 2008; Nogaki, Fu, and Galvin 2007; Stacey and Summerfield 2007; Stacey and Summerfield 2008). The ideal is a limited number of stimuli and simple tasks (Oba, Fu, and Galvin 2011). In this study we chose the melodic contour identification task as the stimulus (Galvin et al., 2007), as was used in Patel et al. (2014) and Lo et al. (2015).

Next to an individualized and computerized training method, a second group will be trained using music therapy. Thus far, to the best of our knowledge, studies using music therapy show a positive effect on QoL and cognition in patient groups with for example dementia and Parkinson, indicating the possibility of a positive effect of music therapy on QoL in CI users (Van de Winckel et al. 2004; Pacchetti et al. 2000). Recently a pilot study by Hütter et al. (2015) in adult CI users was performed using an individualized music therapy program of 10 sessions of 50 minutes, specifically addressed to the individual needs of the CI user. The program was focused on the perception of musical parameters, prosody and complex acoustic situations and started shortly after the initial activation of the speech processor

(Hütter et al. 2015). The preliminary results suggest improvements in subjective music and overall hearing perception. Music therapy consists of training both with speech, music and motoric training by playing the instrument. It has been suggested that exploiting the effects of multimodality by actively playing a musical instrument might be more beneficial for/in creating neuroplasticity, causing the transfer effect perhaps to be more apparent with this type of training (Herholz and Zatorre 2012).

To the best of our knowledge no study has looked into the (possible translational) effect of group-wise music therapy on the perception of music and speech in CI users. By using these training methods in this study we were interested to see if music training or therapy makes a difference on the auditory performance, but also to see whether the improvement of enjoyment of music or the potential of regular meetings with a group of CI users, without any musical influences, might have an effect on the health-related quality of life (QoL). Therefore as a control for a possible group effect or just training effect on QoL and perhaps on the perception of speech and music, a third, control group that only comes together will be incorporated. The third group will not exploit any musical activities.

In this study the effect of a musical training or therapy program, which could be added to the current CI rehabilitation program for the improvement of music perception and enjoyment, will be investigated in a prospective design. A possible positive transfer effect of this training to improvements in speech or music related auditory performance and/or to the quality of life of CI users is investigated.

MATERIALS AND METHODS

Participants

The current study is a prospective study with three training groups that consisted of CI users: 1) the musical training group; 2) the music therapy group; 3) the non-musical training group: the control group

Nineteen post-lingually deafened, adult CI users were recruited via the University Medical Center Groningen (UMCG; see Table 1 for more details). All participants were native Dutch speakers, had a CI for longer than one year, and had no neurological disorders. One of the CI users was a bilateral CI user. Four CI users were bimodal users. Before the study started, written and oral information about the protocol was provided, and informed consent was obtained from all participants. The travel costs and the testing time were financially reimbursed in accordance with the department policy.

Procedures

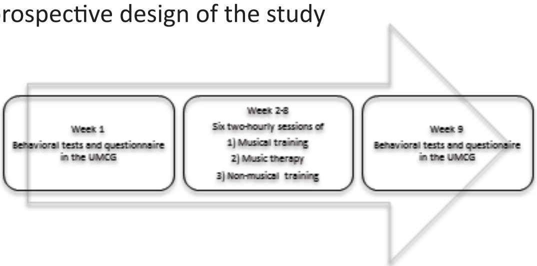
The prospective design of the study in time is depicted in Flowchart 1. Before the training, all participants were first tested with the baseline tests in week 1. These tests constituted of behavioral tests (word, speech, gender and emotion identification and melodic contour

TABLE 1. Demographic characteristics of the CI users.

	Musical Training	Music Therapy	Non-musical Training
Gender (M:F)	3:3	3:4	5:1
Age range (Mean (yrs))	70-78 (73)	56-71 (64)	65-80 (72)
Brand CI			
Cochlear	5	5	3
CI24R CS		1	
CI24RE CA	2	2	3
CI24R CA	1	1	
Ci24R k	1		
CI512	1	1	
Advanced Bionics	1	2	3 (1 bilateral user)
HiRes 90K Helix	1	2	3
Etiology			
Unknown	5	7	3
Sudden deafness			1
Trauma			1
Progressive hearing loss	1		1
Bimodal	2	1	1
Years of CI use (range (yrs))	4,8 (1-11)	4.14 (1-9)	3.0 (1-5)

identification) and a quality of life questionnaire. After the first set of baseline tests in week 1 the CI users were randomly distributed between the three training groups. Due to the small number of participants, no matching was attempted between the three groups. The music therapy group had seven participants; the musical training and non-musical training groups both had six participants. The training sessions were completed within weeks 2-8, and the last week (week 9) constituted the same baseline tests from week 1.

Flowchart 1. The prospective design of the study



Behavioral tests

The behavioral tests before (week 1) and after (week 9) training were conducted in an anechoic chamber at UMCG. Total testing time was two hours including the filling of the questionnaire. All CI users used their own CI(s), with no HA in the case of bimodal users, during testing. The participants were asked to put the CI on their daily life settings and to not change these settings during testing. All CI users were seated facing a touch screen (A1 AOD 1908, GPEG International, Woolwich, UK) and a speaker at a 1-meter distance (Tannoy precision 8D; Tannoy Ltd., North Lanarkshire, UK). Stimuli were presented using iStar (http://tigerspeech.com/istar/), for the words and sentences, and Angelsound™ (Emily Shannon Fu Foundation, http://www.angelsound.tigerspeech.com/), for non-speech tests – i.e. emotion identification and melodic contour identification (MCI). All stimuli were played via a Windows computer with an Asus Virtuoso Audio Device soundcard (ASUSTeK Computer Inc. Fremont. USA). Converted to an analogue signal via a DA10 digital-to-analog converter (Lavry Engineering Inc., Washington. USA) the stimulus was played at 65 dBSPL in sound field. Except for the noises of the speech stimuli, the root mean square (RMS) intensity of all stimuli was normalized to the same value. Calibration was performed with a manikin (KEMAR, GRAS) and a sound-pressure level meter (Type 2610, Brüel Kjær and Sound & Vibration Analyser, Svan 979 from Svantek). Verbal responses on the speech tests were scored online by a student assistant in the adjacent room, as well as recorded using a DR-100 digital voice recorder (Tascam, California, USA) for offline double-check of the responses when needed.

Word identification

The first speech perception task was word identification. Stimuli included digital recordings of meaningful, monosyllabic Dutch words in CVC format [e.g. bus (‘bus’ in English), vaak (‘often’), nieuw (‘new’), etc.] taken from the clinically used NVA test (merged). Twelve lists, each of which contains twelve words spoken by a female talker, were used.

Word identification was tested in four conditions: in quiet and in steady, speech-shaped noise at three signal-to-noise ratio’s (SNRs) (+10, +5 and 0 dB). One randomly selected list out of 12 lists was used to test each condition. No list of words was repeated within a participant. The words were randomly presented. The participant was asked to repeat the word out loud as accurately as possible, and if in doubt, to guess. The software automatically calculated the percentage correct of the phonemes. Stimuli were only played once and no feedback was provided.

Sentence identification

The second speech perception task was sentence identification. Sentences used were syntactically correct Dutch sentences with a meaning and a semantic context (Plomp and

Mimpen 1979). The corpus contains digital recordings of 10 lists of 13 sentences (4 to 8 words per sentence) spoken by a female talker. Sentence identification was measured using three types of noise: 1) steady, speech-shaped noise; 2) fluctuating, speech-shaped noise; and 3) 6-talker babble (Yang and Fu 2005).

Sentence identification was measured in quiet and in noise. One list of 13 sentences was used to test each condition. Sentence lists were randomly chosen from the 10 lists in the test corpus. No list was repeated per participant per session. The participant was asked to repeat the sentence out loud as accurately as possible. The observer in the adjacent room scored the words in the sentence correctly identified. In quiet only, the performance was calculated in terms of the percentage correct of words in the test list correctly identified. For the noise conditions, the speech reception threshold (SRT), defined as the SNR needed to give a 50% correct full sentence identification, was measured using an adaptive one-up/one-down procedure (Plomp and Mimpen 1979). The sentence and noise were presented at a target SNR and the participant was asked to repeat the sentence as accurately as possible. If all words in the sentence were correctly repeated, the SNR was reduced by 2 dB; if not all words were correctly repeated, the SNR was increased by 2 dB. The average of the reversals in SNR between trials 4-13 was reported as the SRT. To target as accurately as possible the SRT within the limited number of sentences, the initial SNR was set to +2 dB for the steady noise condition, and to +6 dB for the fluctuating and babble noise. Note that the first sentence was repeated and the SNR increased until the participant repeated the entire sentence correctly.

Emotion identification

The third behavioral test was a vocal emotion identification test. Stimuli were digital recordings of a nonce word [nutohɔmsɛpikɑŋ] made by Goudbeek and Broersma (2010) and also described and used in (merged). The nonce word was originally produced by eight professional Dutch actors with eight target emotions (‘joy’, ‘pride’, ‘anger’, ‘fear’, ‘tenderness’, ‘relief’, ‘sadness’, and ‘irritation’). Based on a pilot study with three normal hearing listeners, four actors (two female, two male) and four emotions (‘joy’, ‘anger’, ‘relief’ and ‘sadness’) were chosen for formal testing. The four emotions were selected to represent all corners of the emotion matrix based on the prevalence or absence of arousal (defined as the difference between high and low arousal emotions) or valance (defined as the difference between positive and negative emotions): 1) joy (high arousal, positive valence); 2) anger (high arousal, negative valence. 3) relief (low arousal, positive valence); and 4) sadness (low arousal, negative valence). Two recordings of each emotion from each actor were used, producing a total of 32 tokens (4 actors × 4 emotions × 2 utterances).

Participants were first familiarized with the emotion task. For the familiarization session, we have used the same target emotions as the actual test, but produced by four other actors that were not used for formal testing. In both familiarization and data collection sessions, the target emotion was randomly selected from the stimulus set and presented over the loudspeaker. Subjects indicated the emotion by touching one of four response boxes on the touch screen labeled: ‘anger,’ ‘sadness,’ ‘joy,’ and ‘relief’. During familiarization, only visual feedback was provided on the screen in case of a correct answer, showing the emotion. In case of an incorrect answer, audio-visual feedback was provided for the correct and incorrect response, showing the emotion and playing the emotion. The actual data collection was identical to familiarization, but no feedback was provided. The software automatically calculated the percent correct score.

Melodic contour identification

The fourth behavioral test was based on a music task: the identification of the contour of a melody. The melodic contour identification (MCI) task as developed by Fu and Galvin (2007) for testing the ability of CI users in identifying melodies with different contours and different semitone spacing. The MCI test consists of nine melodic contours with 5 notes, each with changes in pitch pattern: “Rising,” “Flat,” “Falling”, “Flat-Rising,” “Falling-Rising,” “Rising-Flat,” “Falling-Flat,” “Rising-Falling,” “Flat-Falling”. The A3 (220 Hz) was always the lowest note in the contours. The semitones between the successive notes were 1, 2 or 3 semitones. The duration of each note in the contour was 250 millisecond (ms). The silent interval between notes was 50 ms. The target instruments used in the testing were the piano or the organ (similar to Galvin, Fu, and Oba (2008)). MCI was tested once in quiet and twice with a competing masker instrument, as in Galvin, Fu, and Oba (2009). The masker instrument was the piano with a “Flat” contour. The base pitch of the masker was either an overlapping pitch (A3 (220 Hz) or a non-overlapping pitch (A5 (880 Hz)). This resulted in a total of six conditions: 1) piano (no masker), 2) piano with the A3, 3) piano with the A5 masker and: 1) organ (no masker), 2) organ with the A3 masker, and 3) organ with the A5 masker. The masker started and stopped at the same time as the target contour.

Questionnaires

Nijmegen Cochlear Implant Questionnaire

In weeks 1 and 9 all CI users were also asked to fill a health-related quality of life questionnaire (HRQoL), the Nijmegen Cochlear Implant Questionnaire (NCIQ), a validated CI-specific HRQoL instrument (Hinderink, Krabbe, and Van Den Broek 2000). The questionnaire consisted of six different domains that included 10 statements with a 5-point response scale. The domains were: sound perception basic, sound perception advanced, speech production, social functioning, and psychological functioning. Per statement, the scores could vary between 0 and 100 (lowest and highest, respectively). The total score was calculated as the average of the 6 domains.

Subjective perceptual skills in the music therapy group

In weeks 2 - 8 the music therapy group filled an additional, non-validated questionnaire, as part of the music therapy project. A short survey was done after every therapy session. In this survey participants could judge if they felt that they improved on different auditory tasks. The CI users could score the questions from 1-10, where 1 was the poorest and 10 the best score. The questions related to the different elements of the therapy.
Did you notice an improvement for:

- Rhythm
- Musical speech
- Perception of music
- Playing music?

STATISTICS

The results of the five behavioral tests were statistically analyzed using IBM SPSS statistics version 22. Repeated measures ANOVA's were used for the behavioral tests and the questionnaire results both for between and within group results. The factors used in the ANOVA's were the three groups (musical training, music therapy and non-musical training) and the conditions per test: for word identification the factors used were the four conditions (quiet, +10, +5 and 0 dB SNR); for sentence identification the three different noises (stationary, fluctuating and babble); for emotion identification the before and after scores; for melodic contour identification per instrument the three different conditions (no masker, A3, A5). For emotion identification also a repeated measures ANOVA for the music therapy group only was used. A p-level of < 0.05 was considered significant and was corrected in case of multiple testing. In word identification and the emotion identification tests, to correct for the skewed data based on the ceiling effect, the percent correct scores were log-transferred before applying the ANOVA.

Training

In weeks 2-8, training was provided. During the training and therapy sessions the CI users were allowed to wear their hearing aid if they were bimodal users, to make the training and therapy as comparable to reality as possible. Nevertheless during testing only the CI was used to see what the effect of the intervention was on hearing with a CI only. Furthermore the results are in this way not interfered by bimodality in the testing. The bilateral CI user was allowed to use both CI's during testing and training.

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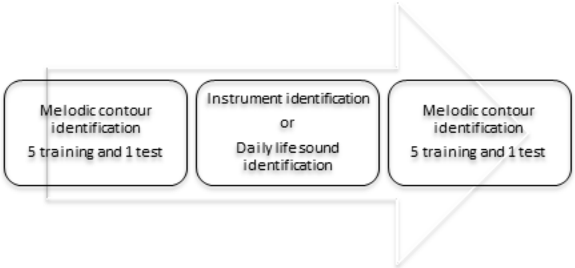
Musical training

The musical training of the study was based on MCI, and was provided via a customized computer program (Galvin, Fu, and Nogaki 2007). In the training different instruments than the ones used in testing, i.e., piano and organ, were used (violin, glockenspiel or trumpet). Stimuli were similar to the MCI described above in baseline testing, and were played using Angelsound (Emily Shannon Fu Foundation. http://angelsound.tigerspeech.com/). Each CI user was seated in a separate room, facing a personal computer and two loudspeakers. The musical training consisted of six, weekly sessions of two hours with a 15 minutes break in the middle. If needed the CI users could ask the help of the assistants that were available at every session for technical problems. The assistants set up the computers and speakers before every session. Only during the first session, the CI users would get started with the sessions by student assistants. The computer was started and the students helped the CI users with familiarization of the test software. After observing one round of training the assistants left. They were available in case of questions or computer problems. Flowchart 2 shows the procedure in time.

At the beginning of each session a written explanation of the exercises for that particular session was provided. The exercises for the melodic contour identification (MCI) went from relatively easy to difficult (Galvin, Fu, and Nogaki 2007). An easy exercise was training with a distance of six semitones between the five notes of the contour; a difficult exercise was training with a distance of only one semitone. A total of five exercises per instrument were completed. During the exercises direct audio-visual feedback was provided in case of an incorrect answer. The feedback involved playing the correct and wrong melodic contours one after another, while on the screen the melodic contour was depicted at the same time. After the five exercises the training per instrument ended with a test. During the test, all semitone distances (one to five) and all nine melodic contours were randomly presented. Furthermore, no feedback was provided. Per instrument a total of six rounds of MCI was completed per participant; five training rounds, and one test. After a full round with one instrument the participants trained with a different task: instruments identification or daily life sound identification. Instrument recognition involved recognizing different instruments by the sound only, choosing from nine different instruments. The daily life sound identification involved recognizing different daily life sounds choosing from options. Examples are recognizing a baby crying, a cat meowing or a car honking the horn. Both involved audiovisual feedback, in the same way as described for MCI. This was done to diversify the training session. After one of these in-between exercises the participants continued with the training of the MCI with a new instrument. Flowchart 2 depicts the set-up of the sessions.

Flowchart 2: The design of the musical training sessions



Music therapy

We have included music therapy as a bridge between musical training and non-musical training. Music therapy, differently than computerized music training, consists of six different types of therapy and training exercises ranging from music only to music related speech perception and to singing, as well as the motor training of playing an actual instrument. Another important difference is that it is interactive in its nature, conducted under supervision of music therapists and in interaction with both therapists and the other participants. The method used is based on practice based evidence using a bottom up approach i.e. the interaction between the therapists and the clients form the sessions. Reflection and feedback are the baseline for the changes to the first model (Migchelbrink and Brinkman 2000). For an extensive report on the development of the training in Dutch see: https://figshare.com/s/db66eb0714a5bd9496d8.

The music therapy sessions were organized under the supervision of three music therapy students and their lecturer and supervisor from the Hogeschool Utrecht, Amersfoort. All sessions were held in the activity room of the rehabilitation center of the CI team of the Northern-Netherlands and were always accompanied by the music therapy students and one of the members of the CI team.

In total the music therapy protocol consisted of six weekly sessions of two hours, with a break of 15 minutes in every session. After each therapy session, this session was evaluated by all involved individuals and, if necessary, changed in accordance to their comments. The therapy sessions were conducted in a group, mostly in a circle, with the CI users facing each other. For some exercises the therapists arranged the CI users in such a way that they had to rely only on the acoustic signal. For example, in an exercise called ‘the bus’: a bus driver gets in the bus (a row of chairs behind each other, respectively) with an instrument playing a rhythm; a passenger gets in the bus behind the bus driver and starts to play a different rhythm to which the bus driver has to match his or her rhythm; a second passenger enters the bus and starts to play a new rhythm to which both the bus driver and the first passenger have to match their rhythms etc. All sessions were accompanied by different musical instruments, such as a guitar, piano, drums and xylophone, played by both the music therapy students as well as the CI users. Furthermore singing and improvising was encouraged.

The music therapy involved different elements of the perception and enjoyment of music and music-related speech tasks. The elements of the sessions had a construction based on the literature of the perception of music and the elements of music with CI's (Gfeller et al. 2000; Fuller et al. under revision; McDermott 2004) from rather easy to perceive for CI users – rhythm – to difficult to perceive – improvising with music. The exercises themselves also had a gradual build up from easy rhythms with for example one instrument, to more difficult rhythms with more instruments at once. All elements were practiced via different exercises that were always first explained and shown by the therapy students. Afterwards the CI users were allowed to discuss what difficulties they encountered or what they felt.
All sessions consisted at least of the following elements, from easy to difficult:

- Rhythm
- Emotion Identification
- Musical Speech
- Singing
- Playing Music
- Improvising with music

We have included non-musical training as a control group that did not perform any musical activities, but that did need to interact with each other during different tasks. This was done to see whether also non-music related interactions made a difference for example for quality of life.

The first two sessions of two hours involved a writing course with a professional writing coach at the boat of the coach; the second pair of sessions involved a cooking course during which the participants had to collaborate to prepare different dishes at the kitchen located at the school of the deaf; the last two sessions involved a wood workshop during which the participants had to build a birdhouse under the supervision of a woodwork teacher also held at the school of the deaf. A member of the CI-team, the social worker, accompanied all sessions to explain the tasks and be available if there were any difficulties or questions. The non-musical training consisted of interactive group activities that had no connection to music. The total training consisted of a total of six weekly sessions of two hours, with a break of 15 minutes in the middle.

RESULTS

Word identification

Figure 1 shows the results for the word identification test before and after the training for the three groups in percent correct scores. The figure shows that there are no notable differences for word identification between before and after the training, or between the different training groups. The repeated measures ANOVA used all four conditions (quiet, +10, +5 and 0 dB SNR) and all three training groups (musical training, music therapy, non-musical training) as factors. No significant effect of training for the word identification within or between the training groups between before and after the sessions was shown.

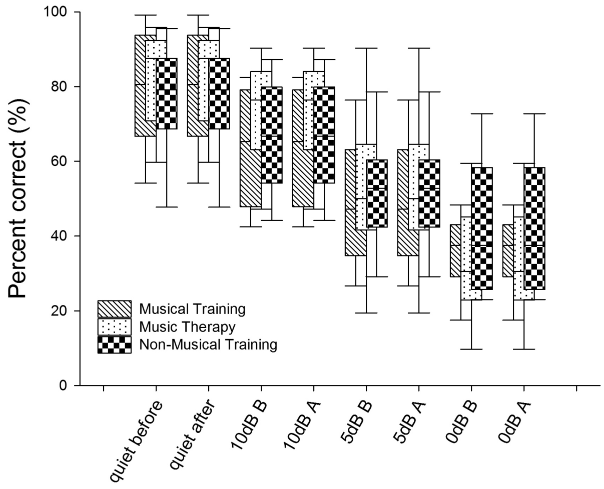


Figure 1. The word identification scores shown for the three different groups in percent correct scores. On the x-axis the letter 'B' refers to the results before training; the letter 'A' to the results after training.

Sentence identification

Figure 2 shows the results for the sentence identification test before and after the training for the three groups for the three different noise conditions. The figure shows that there are no notable differences between before and after the training, or between the different training groups. In the ANOVA the quiet condition was not used, as it is a percent correct score and not a speech reception threshold. The repeated measures ANOVA was built using the three different SRT scores (stationary, fluctuating and babble) for the three different training groups (musical training, music therapy, non-musical training). The results showed no significant effect within the training groups before and after the training. Also, no differences between the training groups before and after the training were shown.

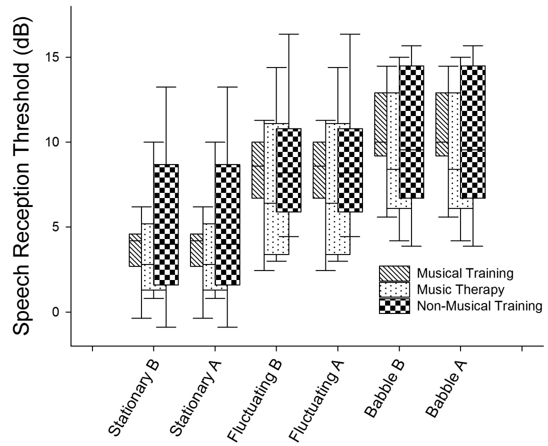


Figure 2. The mean sentence identification is shown in SRT's (dB) plotted for the three training groups. From left to right results are shown for the three different noises: stationary, fluctuating, babble noise, respectively. On the x-axis the letter 'B' refers to the results before training; the letter 'A' to the results after training.

Emotion identification

Figure 3 shows the results for the vocal emotion identification scores before and after the training sessions for the three groups in percent correct scores. The figure shows a possible positive effect of music therapy on the vocal emotion identification. A single, repeated measures ANOVA with the music therapy group and the emotion scores as factors, shows a significant within subject effect ($F(1)=8.898$; $p=0.025$). The repeated measures ANOVA for the three groups did not show an effect between the different training groups. Altogether this could possibly indicate that music therapy could have a possible positive effect on emotion recognition, even though no significant difference between the three groups was shown.

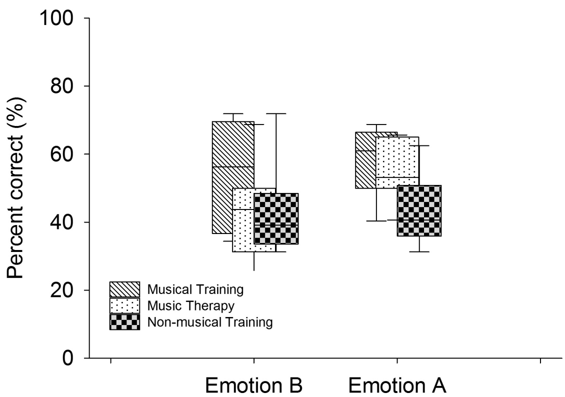


Figure 3. The mean emotion identification shown for the three training groups on the left before and on the right after the training sessions. On the x-axis the letter 'B' refers to the results before training; the letter 'A' to the results after training.

Piano

Figure 4 shows that the musical training group might improve for MCI for piano on the A3 and A5 condition. The other training groups showed no notable improvement after the training for MCI for piano in the figure. The repeated measures ANOVA for the MCI using three piano conditions (no masker, A3, A5) and the three training groups (musical training, music therapy, non-musical training) as factors showed no effect within groups. The between groups ANOVA showed a significant effect of the different training groups (F(2)=4.481, p=0.03) for MCI. Post-hoc tests showed a significant positive effect of the musical training opposed to the non-musical training (p=0.03), but not to the music therapy group. This could indicate that musical training could have a positive effect on melodic contour identification and a better effect than non-musical training, but not better than music therapy.

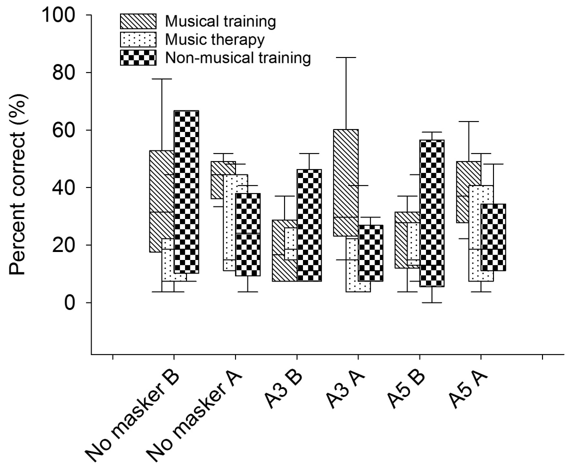


Figure 4. The mean melodic contour identification shown for piano for the three training groups. The three conditions shown from left to right are no masker, A3 masker, and A5 masker. On the x-axis the letter 'B' refers to the results before training; the letter 'A' to the results after training.

Organ

Figure 5 shows that that the musical training group might improve for MCI for organ on the no masker and the A5 condition. The other groups show no notable improvement between before and after the training for MCI for organ in the figure. The repeated measures ANOVA using all three conditions (no masker, A3, A5) and all three groups as factors showed an effect for both MCI (F(1.97)=6.865; p=0.003) and for the different training groups (F(3.95)=3.236; p=0.025) within subject. Between subjects an effect for the different groups was shown (F(2)=5.923; p=0.012). Post-hoc tests indicate a possible effect of musical training opposed to both music therapy (p=0.038) and non-musical training (p=0.018). This could indicate that musical training could have a positive effect on melodic contour identification for both piano and organ.

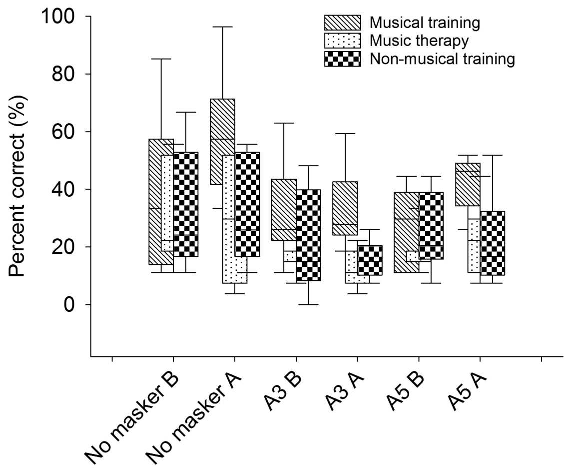


Figure 5. The mean melodic contour identification shown for organ for the three training groups. The three conditions shown from left to right are no masker, A3 masker, and A5 masker. On the x-axis the letter 'B' refers to the results before training; the letter 'A' to the results after training.

Quality of life

Figure 6 shows the total scores before and after the training sessions for the NCIQ. Repeated measures ANOVA showed no effect of the training on the quality of life within and between the three training groups.

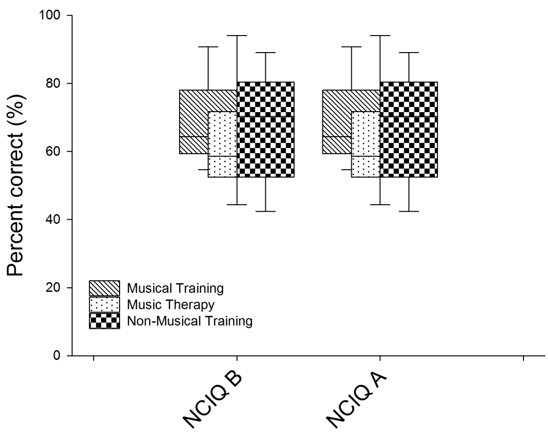


Figure 6. The mean quality of life shown for the three training groups. On the x-axis the letter 'B' refers to the results before training; the letter 'A' to the results after training.

Subjective perceptual skills in the music therapy group

Figure 7 shows the result of the survey in the music therapy group. The figure shows a trend that all participants find themselves improving on all tasks.

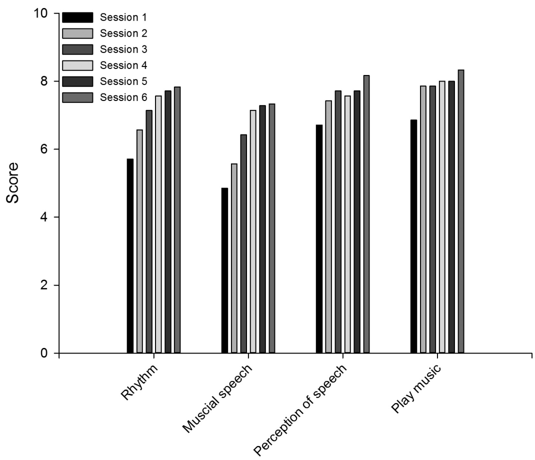


Figure 7. The subjective ability to perceive rhythm, musical speech, music and to play music in the music therapy group per session. The first session on the left, the sixth on the right.

DISCUSSION

The main goal of the current study was to explore the feasibility of implementing a musical training program for CI users in the clinic. A second goal was to investigate differences in training outcomes among different training approaches and to determine which approach was most effective during a short training period. We investigated the effect of three different training approaches (musical training, music therapy and non-musical training) on CI users' auditory perception performance (within and cross domain) and QoL measures. To compare the outcomes of this study to the results for NH musicians listening to CI simulations (Fuller et al. 2014a), the same behavioral tests were used: speech identification, vocal emotion identification and melodic contour identification. A significant within-domain effect (improved melodic contour identification in the musical training group) and a small cross-domain training effect (improved vocal emotion identification in the music therapy group) were observed, but no effects on speech identification (in all three groups) were shown. The music therapy group did show enhanced subjective perceptual skills. No effects on QoL were reported for any of the training groups. A general point of discussion is the small group size that might influence the power and there with the outcome of the current study. We would like to emphasize that the current study was a feasibility study and that future studies should focus on increasing the power by adding more participants, as well as training for longer periods of the time.

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Effect of music training on speech perception in noise

No transfer of learning for the three different training groups was found to speech perception (words or sentences). Within this training study, we were not able to replicate the preliminary findings of Patel (2014) and Lo et al. (2015). Patel (2014) showed a small cross-domain benefit for musical training in two CI users from music to speech. One subject showed improved sentence recognition in noise, the other subject improved perception of prosody in speech. Lo et al. (2015) showed a positive effect of musical training on question/statement identification and consonant discrimination in 16 CI users. The lack of strong cross-domain learning in the present study may have been due to the speech outcome measures used. Sentence recognition in noise may depend on perception of voice pitch to some extent, but also involves other high-level cognitive and linguistic processing. The cross-domain music training benefits observed in previous studies may have been due to minimal linguistic context (e.g., consonant identification, as in Lo et al., 2015, syllable perception, as in Zuk, 2013, prosody perception, as in Patel et al., 2014). Perception tests such as emotion identification that explicitly depend on voice pitch perception may have revealed stronger cross-domain training effects (Fuller et al., 2014).

It should be noted that cross-domain music training effects are often small and inconsistent in previous studies. Only a small effect of musical training for speech understanding in noise has been observed in children, young and older adults (Parbery-Clark et al. 2009; Strait and Kraus 2011; Parbery-Clark et al. 2011). Zendel and Alain (2012) showed a significant musician effect for speech perception in noise only for older adults, but no effect for adults younger than 40 years old. Fuller et al. (2014b) showed no effect using normal acoustical stimuli with steady, fluctuating and babble noise, but a small effect using CI simulations. Ruggles et al. (2014) did not find a musician effect for voiced or whispered speech in continuous or gated noise. Larger musician effects have been observed for speech understanding with speech maskers (speech-on-speech). Speech-on-speech perception is an interesting entity to study for potential music training effects. Whereas speech understanding in noise largely involves energetic masking (Gaudrain and Carlyon 2013), speech understanding with competing speech involves both energetic and informational masking, due to lexical content and acoustic similarities between the target and masker talkers (Darwin, Brungart, and Simpson 2003). Voice pitch differences are an important cue for segregating competing talkers. Theoretically, improved pitch perception via musical training would aid talker segregation (Herholz and Zatorre 2012; Kraus, Zatorre, and Strait 2014; Zatorre 2013). Some previous studies have shown significant musician effects for speech-on-speech perception (Swaminathan et al. 2015; Başkent and Gaudrain 2016), while others have not (Boebinger et al. 2015). It is possible that musician effects for speech-on-speech perception may be related to better segregation of other acoustic cues besides voice pitch (Başkent and Gaudrain 2016).

Investigating the musician effect on speech perception in CI users or in NH subjects listening to CI simulations (i.e., under conditions of spectro-temporal degradation) is a relatively understudied and new topic. Our recent research with NH subjects listening to CI simulations showed only a small musician effect for speech perception, significant only for word recognition in noise (Fuller et al. 2014b). Surprisingly, no musician effect on speech perception in noise was observed in NH subjects listening to unprocessed speech. Research thus far has shown mixed results for cross-domain transfer of music training to speech perception in noise. Future research should carefully consider speech outcome measures that depend strongly on perception that is enhanced by music training, most notably pitch perception. If pitch is not a strong cue for a particular speech perception task, then it seems unlikely that music training might benefit that particular speech task. Alternatively, music training may improve working memory and overall pattern perception. Perceptual tasks that explicitly test working memory may further reveal musician advantages.

Effect of music training on emotion identification

As noted above, music training may especially benefit speech perception that depends strongly on voice pitch perception. One such listening task is vocal emotion recognition, which depends strongly on voice pitch perception and is difficult for CI users due to the coarse spectral resolution that does not support harmonic pitch perception (see Moore and Carlyon, 2005 for review). Vocal emotion identification has been shown to be much better in NH listeners than in CI users (House 1994; Pereira 2000; Xin, Fu, and Galvin 2007). Even when listening to acoustic CI simulations with only 4-8 spectral channels, NH listeners have been shown to outperform CI users (Xin, Fu, and Galvin 2007). Gilbers et al. (2015) suggested that NH listeners use mainly the mean pitch for emotion identification, whether listening to unprocessed stimuli or to CI simulations; while real CI users, on the other hand, seemed to rely on pitch ranges conveyed by the temporal modulations. NH musicians have also been shown to outperform NH non-musicians for emotion identification (Thompson, Schellenberg, and Husain 2004).

Our recent CI simulation study in NH musicians and non-musicians showed a significant musician advantage for emotion identification using normal and CI simulated stimuli (Fuller et al. 2014b). Thus, even after degrading the fine structure of the signal musicians were able to identify emotions better. It was suggested that the musician advantage was based on a better perception of pitch cues, even in CI simulations. While pitch perception strongly contributes to emotion identification, other cues that co-vary with F0 also contribute, such as duration (longer for sad, shorter for happy), overall amplitude (higher for happy, lower for sad), tempo and pausing (Luo et al. 2009; Hubbard and Assmann 2013). These co-varying cues were not controlled for in Fuller et al. (2014b) or in the present study. Hence, while emotion identification heavily relies on pitch cues, these other cues may have also contributed to the present pattern of results.

If so, musical training may similarly benefit CI users' vocal emotion identification. However, it should be noted that the extensive training experienced by NH musicians might not be comparable to short-term training with degraded signals in CI users.

In this study, emotion identification was tested using a nonce word, eliminating semantic context cues. We found a positive effect of music therapy on emotion identification, possibly due to improved pitch perception after the training or to improved perception of other co-varying cues such as amplitude and duration. However, no training effect was shown for the other two training groups. One explanation might be that, in contrast to the musical training and the control group, the music therapy group was specifically trained for emotion identification. During the therapy sessions, vocal and instrumental emotion identification was practiced. For example, a member of the group would choose an emotion from a series and play it on an instrument. The other group members' task was to identify the emotion. In the vocal prosody exercise, emotion identification was practiced using a song or a story line that was sung or spoken by the session leaders. These training approaches might have had a direct positive effect on emotion identification in the music therapy group. Our results suggest that emotion identification can be enhanced by direct training with music or speech, and that the interactive nature of the music therapy may have contributed to a better learning of this task. Further research may shed light on the best approach to train CI users' perception of music and pitch-mediated speech.

Effect of training on MCI

It was not surprising that the music training with MCI improved MCI performance. Training benefits were observed for the piano and, to a larger extent, for the organ. Galvin et al. (2008) reported that mean MCI performance in CI users was poorest with piano and best with organ. Other MCI training studies with CI users also showed that performance with the organ improved most with the training (Galvin et al., 2007, 2009). Perhaps, the organ is more easily trained in CI users because its spectral-temporal content is less complex than for other instruments such as the piano. Lo et al (2015) showed that the biggest effect of training occurred after 1 and 2 weeks of training, maximum improvement, however, was seen after 4 to 6 weeks. As we have conducted no intermediate tests during our series, it is unclear whether the training benefit was maximum. Future studies should adopt in-between tests, as well as an extension of the duration of the study to see whether the maximum effect can be found.

No effect on MCI was shown for the music therapy and the control group. Perhaps an extensive training for a specific task creates a big enough benefit in the short period of six weeks, compared to a non-specific training, such as music therapy. Nevertheless an elongation of the training period might show an improvement in the therapy group as well; the elongation might make the total amount of melodic training comparable between groups. Given the generally heterogeneous composition of groups of CI users, future research could focus on larger groups of CI users to be able to draw more definitive conclusions.

Effect of music training on QoL and subjective perception

There was no effect of training on QoL ratings. It is possible that only such a short period of training was not sufficient to alter the QoL. Music therapy has been previously shown to increase subjective QoL ratings in different patient groups (Hilliard 2003; Walworth et al. 2008). But in our music therapy group, no such effect was observed. Anecdotal reports suggested that the music therapy made CI users feel better about their perceptual skills, that they could better understand other talkers' emotions, and that they began to listen to and better enjoy music. This is in line with a recent study by Hütter et al (2015) that showed an increase in subjective overall music perception after therapy. These self-reports of improved speech and music perception are encouraging and should be more deeply investigated in future research.

This feasibility, training study showed an improvement for MCI and emotion identification, only in the groups that were specifically trained for that task. Music therapy positively influenced the subjective perceptual skills of CI users. Our results might indicate that music training or music therapy might be a useful addition to the rehabilitation program of CI users.

Acknowledgement

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