Auditory, Visual, and Auditory–Visual Perception of Emotions by Individuals With Cochlear Implants, Hearing Aids, and Normal Hearing

Tova Most
Chen Aviner
Tel-Aviv University

This study evaluated the benefits of cochlear implant (CI) with regard to emotion perception of participants differing in their age of implantation, in comparison to hearing aid users and adolescents with normal hearing (NH). Emotion perception was examined by having the participants identify happiness, anger, surprise, sadness, fear, and disgust. The emotional content was placed upon the same neutral sentence. The stimuli were presented in auditory, visual, and combined auditory–visual modes. The results revealed better auditory identification by the participants with NH in comparison to all groups of participants with hearing loss (HL). No differences were found among the groups with HL in each of the 3 modes. Although auditory–visual perception was better than visual-only perception for the participants with NH, no such differentiation was found among the participants with HL. The results question the efficiency of some currently used CIs in providing the acoustic cues required to identify the speaker’s emotional state.

Spoken language communication comprises linguistic information such as lexical items and syntactic pattern, as well as vocal nonverbal information, such as the speaker’s emotional state with respect to the topic or the listener (Mozziconacci, 2002). Both linguistic and nonverbal information are crucial for understanding social interaction (Rieffe & Terwogt, 2000). This study focuses upon nonverbal information, specifically upon the emotional state of the speaker.

Perception of the speaker’s emotional state is based upon auditory as well as visual cues. Banse and Scherer (1996) reported that adults with normal hearing (NH) were able to reliably identify the speaker’s emotional state based solely upon auditory cues. For example, anger is characterized by a high average fundamental frequency, large range of fundamental frequency, as well as a high average intensity and a high rate of speech. In comparison, sadness is characterized by a low average fundamental frequency, low average intensity, long duration, and a slow rate of speech. Thus, auditory perception of the emotion is based primarily upon the following acoustic cues: fundamental frequency characteristics (such as the average, the range, and the shape and the direction of the intonation contour), the average intensity, and the intensity changes along the utterance; the energy distribution in the spectral range, specifically the ratio between the energy in the high frequencies and the energy in the low frequencies; the formant location; and finally, the duration of the production or the rate of speech (Banse & Scherer, 1996; Williams & Stevens, 1972). Murray and Arnott (1993) indicated that the most significant contribution to emotion perception was the fundamental frequency changes along the utterance, after which comes duration, and finally, intensity.

Previous research reported great variations in accurate auditory perception of the different emotions. In general, anger and sadness were found to be easier to identify, whereas surprise and disgust were very difficult to perceive (Banse & Scherer, 1996; Most, Wiesel, & Zaychik, 1993; Pereira, 2000).

Most of the research that investigated emotion perception focused upon perception through the visual mode, or more specifically, upon facial expressions. Based upon findings of studies conducted in

No conflicts of interest were reported. Correspondence should be sent to Tova Most, School of Education, Tel Aviv University, Tel Aviv 69978, Israel (e-mail: tovam@post.tau.ac.il)
different countries on the perception of emotions based on facial expressions, Ekman (1999) indicated that there are universal visual cues for the perception of fear, sadness, happiness, anger, disgust, and surprise. The main visual cues for identifying facial expressions center upon the eyes and the mouth. Fear, anger, and sadness are best identified through the eyes, whereas happiness and disgust are best identified through the mouth. Surprise is equally identified through the eyes or the mouth (Calder, Young, Keane, & Dean, 2000; Sullivan, Ruffman, & Hutton, 2007).

There is a great variability as well in the accurate perception of emotions through the visual mode. Previous research reported that happiness could be perceived most accurately. Emotions such as fear, disgust, and surprise were difficult to identify, whereas anger and sadness were in-between (Calder et al., 2000; Hosie, Gray, Russell, Scott, & Hunter, 1998; Montagne, Kessels, Frigerio, De Haan, & Perret, 2005; Most et al., 1993; Wagner, McDonald, & Manstead, 1986).

In general, in most social interactions, emotions are transmitted through the auditory–visual mode (Scherer & Ellgring, 2007). When comparing the perception of emotions through each of the sensory modes separately, it was found that in comparison to the perception level of the auditory mode, emotions were better perceived through the visual mode (Hess, Kappas, & Scherer, 1988; Most et al., 1993; Rigo & Liberman, 1989; Wallbott & Scherer, 1986). Nevertheless, auditory cues are very important because they provide information in situations where facial information is not available (Shackman & Pollak, 2005). Combined auditory–visual cues always resulted in better emotion perception when compared to the presentation of solely auditory information (Most et al., 1993; Rigo & Liberman, 1989; Wallbott & Scherer, 1986); however, this perception was not always better than solely visual perception. For example, Most et al. (1993) reported better emotion perception of adults with NH through the auditory–visual mode, when compared to any of the other modes used alone, whereas others, such as Wallbott and Scherer (1986), reported similar perception through the auditory–visual mode and the visual mode alone.

Emotion Perception by Individuals With Hearing Loss Using Hearing Aids

As a result of sensorineural hearing loss, many individuals may have difficulties perceiving the spoken signal in general, as well as difficulties perceiving auditory nonverbal cues of emotions. Difficulties with perceiving information about the emotional state of the speaker may lead to a lack of awareness of the individual's impact upon others, a lack of empathy, and social skills that are not adapted to the situation (Mellon, 2000). Much of the acoustic information about emotions is located in the low-frequency range, and many individuals with hearing loss have residual hearing in this range. Nevertheless, sensorineural hearing loss negatively affects psychoacoustic abilities such as frequency resolution, frequency discrimination, or time resolution, all of which are necessary in order to accurately perceive emotional information (Moore, 1996). Studies on the auditory perception of emotions by children, youth, and adults with hearing loss who use hearing aids (HAs) reported lower performance in comparison to individuals with NH (Most et al., 1993; Oster & Risberg, 1986; Rigo & Liberman, 1989; Shinall, 2005). Rigo and Liberman (1989) reported a negative correlation between the identification of emotions and the degree of hearing loss in the lower frequencies, whereas on the other hand Most et al. (1993), did not report such correlation. All the persons with hearing loss who participated in this study received low auditory scores in emotion perception, without any correlation to the degree of hearing loss. It should be noted, however, that the participants in this study had severe and profound hearing loss, whereas those examined by Rigo and Liberman had a wide range of hearing loss from mild and moderate to severe. Most et al. reported a similar hierarchy with regards to the perception of different emotions through the auditory mode by youth with and without hearing loss.

Previous studies on the perception of emotions through the visual mode by people with hearing loss provided different results. Although some reported on performance similar to that of individuals with NH (Dyck, Farrugia, Shochet, & Holmes-Brown, 2004;
Hosie et al., 1998; McCullough et al., 2005; Rollman & Harrison, 1996; Weisel, 1985), others reported that the individuals with hearing loss also exhibited lower performance through the visual mode (Bachara, Raphael, & Phelan, 1980; Dyck & Denver, 2003; Most et al., 1993; Weisel & Bar-Lev, 1992). Most of the research findings did not report any significant correlation between the degree of hearing loss and the ability to accurately identify facial expressions (Dyck & Denver, 2003; Most et al., 1993). The lower performance of the individuals with hearing loss when perceiving visual emotional information was explained by the fact that the ability to perceive emotions develops in the context of spoken language. When the infant watches facial expression while hearing matching vocalization, he/she can more easily identify the resultant emotion (Walker-Andrews & Lennon, 1991). The development of social knowledge and social skills and the acquisition of theory of mind in a child with hearing loss who is in a hearing environment and who is not exposed to a rich natural spoken language might be delayed (Peterson & Siegal, 1995; Weisel & Bar-Lev, 1992). Another explanation might be the fact that individuals who communicate in spoken language focus upon the mouth in order to lip-read, and therefore, they might miss information around the eyes that might be relevant to emotions (Rigo & Liberman, 1989).

Just as with individuals with NH, those with hearing loss exhibited better perception of emotions through the visual mode and the combined auditory–visual mode than the perception through the auditory mode. However, in contrast to hearing individuals, the level of emotion perceived by individuals with hearing loss through the combined auditory–visual mode did not exceed that of emotions perceived through the visual mode (Most et al., 1993; Rigo & Liberman, 1989). In other words, they did not benefit from the addition of auditory information to the visual mode.

**Emotion Perception by Individuals With Hearing Loss Using Cochlear Implants**

The above section reports on emotion perception by individuals with hearing loss who were using HAs. Cochlear implant (CI) technology has opened up rehabilitation options for the use of spoken language among individuals with severe and profound hearing loss. The use of the CI has shown that it increases the audibility of the speech signal and consequently enables better speech perception by children using CI compared to those with a similar degree of hearing loss but who use HAs (Blamey et al., 2001; Calmels et al., 2004; Gestoettner, Hamzavi, Egelierlier, & Baumgartner, 2000; Meyer, Svirski, Kirk, & Miyamoto, 1998; Mildner, Sindija, & Zrinski, 2006). The different studies report on a great difference in an individual's performance as a result of diverse variables, such as age of implantation (Oh et al., 2003; Taitelbaum-Swead et al., 2005), the duration of CI use (Kishon-Rabín al., 2002), and the onset of deafness (Geier, Barker, Opie, & Fisher, 2000). Most such research, however, reported the perception of segmental features of speech.

Much less attention has been given to research on the perception of suprasegmental features, and the results attained did not necessarily favor the CI (Carney, Kienle, & Miyamoto, 1990; Most & Peled, 2007; Peng, Tomblin, & Turner, 2008; Waltzman & Hochberg, 1990; Wu & Yang, 2003). For example, Waltzman and Hochberg (1990) found that children with Nucleus 22-channel CI and children with HAs performed well in perceiving word emphasis and pitch changes. Boothroyd and Eran (1990) reported that perception of syllable number by children using the Nucleus CI did not significantly differ from that of children with HAs, but that children with HAs did perform better at perceiving intonation. In addition, Most and Peled (2007) reported on poorer perception of syllable stress and intonation by children using CI compared to children with severe and profound hearing loss using HA.

Researchers have explained the poor CI performance in perceiving suprasegmental features by suggesting that the implant may not provide sufficient information on the changes in fundamental frequency, which are an important acoustic cue for the perception of suprasegmental features. For example, O’Halpin, Falkoner, Rosen, and Viani (2006) suggested that perception of word emphasis via the CI Nucleus 24 (with Spectral Peak and Advanced...
Combination Encoder) does not rely upon changes in fundamental frequency but rather upon duration and intensity cues. Their methodology consisted of using synthetic speech stimuli with controlled changes for each of the acoustic parameters (amplitude, duration, and fundamental frequency).

Thus, in many current CI systems, the place and the temporal pitch-encoding mechanisms are inadequate, resulting in difficulties when transferring information salient for the perception of suprasegmental features of speech (Carroll and Zeng, 2007).

Just as with the suprasegmental features, auditory perception of the emotional state is cued through changes in fundamental frequency along the utterance, as well as duration and intensity cues (Banse & Scherer, 1996). Despite the importance of emotional content perception for successful communication, only a few research studies have examined this performance by individuals with CI. These research studies examined auditory perception in postlingually deafened adults who use CI, when compared to hearing individuals (Luo, Fu, & Galvin, 2007; Pereira, 2000; Peters, 2006). They reported lower performance in comparison to the hearing controls and a great variation among participants with CI. In addition, after the normalization of the stimuli (controlling the intensity cues of the various emotions), the performance of the participants with CI decreased. In other words, they probably relied upon their perception of intensity cues, and once these cues were controlled, their performance decreased. It should be noted that the normalization did not affect the performance of the control hearing participants in the same manner (Luo et al., 2007; Pereira, 2000).

In summary, the ability to perceive the emotional state of a speaker is very important in communication interaction. Because individuals with severe and profound hearing loss miss a great deal of the verbal content, they rely more heavily on nonverbal cues during interaction. Previous research reported difficulties in the auditory perception of emotions by individuals with hearing loss. Only a few studies were performed with individuals using CI, and these examined the auditory perception of postlingually deafened adults. These studies compared their performance to that of hearing individuals, but no comparison was carried out with individuals wearing HAs. In addition, no comparison was performed with regard to perception via the different sensory modes.

The purpose of this article was to evaluate emotions perception by individuals using CI (implanted at different ages) versus individuals with HAs and individuals with NH. Emotion perception was evaluated through solely the auditory mode, the visual mode, and the combined auditory–visual mode. We hypothesized that the auditory emotion perception of individuals with NH would be superior to that of all participants with hearing loss. We wanted to examine whether CI users would perform differently from HA users in auditory emotion perception. We hypothesized that the early-CI group would perform better than the late-CI group through both the auditory and the auditory–visual modes. We further hypothesized that individuals with NH would perform better through the auditory–visual mode in comparison to the visual mode. We wanted to examine whether individuals with hearing loss—both CI and HA users—would perform better through the auditory–visual mode, in comparison with each of the sensory modes alone. Finally, we wanted to examine the perception of specific emotions through the different modes by all the participants.

**Materials and Methods**

**Participants**

The participants consisted of 40 individuals aged 10–17 years. Thirty participants had prelingual binaural sensorineural hearing loss with no other disabling condition. All had been educated in the regular education system and used spoken language as their means of communication. Ten participants had NH. The 30 participants with hearing loss were divided into three groups of 10 participants each:

1. Ten participants (four males and six females) aged 10:10–15:7 ($M = 13:9$, $SD = 1:7$) were CI users who had been implanted before the age of 6 (range = 2:6–5:6 years, $M = 3:11$, $SD = 1:3$) (early-CI group). The duration of CI usage ranged between 6:9 and 13:1 years ($M = 9:7$, $SD = 2:0$). The hearing loss of all the
participants had been detected early when they were 3–24 months old. All of them had used HAs prior to the implantation.

2. Ten participants (four males and six females) aged 10–17.6 (M = 15:1, SD = 2.7) were CI users who had been implanted after the age of 6 (range = 6.2–16.2 years, M = 11:4, SD = 3.87) (late-CI group). The duration of CI usage ranged between 1 and 6.9 years (M = 3:8, SD = 2:10). The hearing loss of all the participants had been detected when they were 3–38 months old. All of them had used HAs before implantation.

Age 6 years (age of implantation) was used as the cutoff age between the early- and late-CI groups on the basis of previous reports showing significant differences on many variables between children who were implanted before 5 years of age and those implanted after the age of 7 (El-Hakim et al., 2001; Harrison, Gordon, & Mount, 2005; Seung-Ha et al., 2003).

Table 1
<table>
<thead>
<tr>
<th>Emotion</th>
<th>Average (Hz)</th>
<th>Range (Hz)</th>
<th>SD (Hz)</th>
<th>Utterance time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happiness</td>
<td>131</td>
<td>121</td>
<td>33</td>
<td>2.145</td>
</tr>
<tr>
<td>Anger</td>
<td>144</td>
<td>132</td>
<td>40</td>
<td>2.784</td>
</tr>
<tr>
<td>Surprise</td>
<td>163</td>
<td>188</td>
<td>54</td>
<td>2.29</td>
</tr>
<tr>
<td>Sadness</td>
<td>113</td>
<td>60</td>
<td>16</td>
<td>3.362</td>
</tr>
<tr>
<td>Fear</td>
<td>143</td>
<td>110</td>
<td>30</td>
<td>2.75</td>
</tr>
<tr>
<td>Disgust</td>
<td>111</td>
<td>85</td>
<td>21</td>
<td>3.03</td>
</tr>
</tbody>
</table>

The fourth group comprised 10 participants (four males and six females) aged 10.5–16.10 (M = 14:10, SD = 1:11) with hearing within the normal range, with no history of hearing problems or any other disabling condition.

All the participants had received a score above 75% on a written emotion vocabulary test (Weisel & Bar-Lev, 1992) in order to ensure that they were all familiar with the emotions, both linguistically and conceptually.

Instrument

This study used an Identification of Emotion Test (IET) developed by Most and Weisel (Most et al., 1993). A complete description of the test construction is available in Most et al. (1993) who examined adolescents with hearing loss using HAs as well as adolescents with NH. The test had previously been used with adolescents with learning disorders as well (Most & Greenbank, 2000). The test was found to be valid and reliable in both studies. The test includes a total of 36 video-recorded items—six presentations of each of the following emotions: anger, fear, sadness, happiness, disgust, and surprise. Each of the emotions is expressed through the use of the same neutral sentence “I am going out now and I’ll be back later.” Thus, the sentence’s verbal content remains the same throughout the test and differences in emotional content are expressed by auditory and visual nonverbal cues. The emotions are produced by a professional actor using normal voice and speech articulation. Each item lasts 2–3 s, and there is a 10-s break between each of the items. Praat software was used to conduct an acoustic analysis on the test items. Table 1 presents the average fundamental frequency (F0), the SD, the F0 range, and the average duration of the six emotions.

Procedure

The participants with hearing loss were recruited via the SHEMA Organization for the Education and Rehabilitation of Children and Youth with Hearing Impairment. SHEMA is a nonprofit association that serves school-age children (aged 7–18 years) with hearing loss. SHEMA supports the children and their teachers during school hours and in extracurricular activities. The participants with NH were recruited through personal relatives and their
friends. Signed consent forms were obtained from all the parents.

The examiner (C.A.) held three individual sessions with each participant in a quiet room. Each session lasted approximately 20 min. The sessions were a few days apart from each other. At the beginning of the first session, the examiner presented a written emotion vocabulary test, which contained 36 items describing an event that triggers a specific emotion. For example, “Ruthy had a birthday party and many friends came to her party. Ruthy felt...” The participant was asked to select the appropriate emotion from four alternatives: happy, sad, angry, and fear. This test was administered in order to ensure that all the participants were familiar with the concept of the emotions and served as a criterion for participating in the study. Next, the examiner examined the sensory aids and performed the Ling 6-sound test (Ling & Ling, 1978) to ensure that the participants’ sensory aids were functioning and were being used properly. Lastly, the examiner explained the task and used a few items (differing from the test items) for practice. The training items were presented through the audiovisual mode.

The IET was then presented. The test was presented through a different mode during each of the sessions. There were three modes of presentation: an auditory mode—during which the screen was darkened and the participant listened to the test items at a normal conversational level (70 dBSPL at the participant’s seat); a visual mode—during which the participant only watched the screen without sound; and an auditory–visual mode—during which the participant watched the screen while listening. The order of presentation modes was randomized. The test items were presented through the use of a portable computer (IBM T43) connected to two loudspeakers (SONY). The participant was seated facing the screen, positioned about 1 m away from the screen. The two loudspeakers were located on both sides of the computer at a 45-degree angle from the participant’s seat. After each item of the test had been presented, the participant was asked to mark his/her answer on a response form on which the six emotions were presented. The order of the items was different for each presentation mode.

Results

Each of the participants in each of the four groups received three emotion perception scores—one for each presentation mode: auditory, visual, and auditory–visual. Because closed-set responses were used with the six alternatives, the scores were adjusted according to the following formula by Boothroyd (1988) to take guessing into account:

$$\text{Corrected score} = \frac{\text{Uncorrected score} - \% \text{ probability for correct answer}}{\% \text{ probability for error}} \times 100.$$ 

Group Results

Table 2 presents the corrected mean percent scores and the standard deviations for each of the four groups in each of the three modes.

One-way ANOVAs were conducted with repeated measures. The independent variable was the group, the dependent variable was the percent of correct emotion identification, and the repeated measures were the three modes. The analysis revealed a significant main effect of group, $F(3, 36) = 6.47, p < .01,$
a significant main effect of mode, $F(2, 35) = 303.88$, $p < .001$, and significant interaction between group and mode, $F(6, 70) = 5.26$, $p < .001$.

One-way ANOVAs were conducted for each of the presentation modes. There were no significant differences between the groups with regard to the visual or the auditory–visual modes. Multiple contrasts (Einot & Gabriel, 1975) among the auditory scores of the four groups revealed a significant difference. The hearing group received a significantly better score than the other groups. None of the other groups were significantly different from each other. Nevertheless, an inspection of the mean scores showed that the mean identification score of the early-CI was better than that of the late-CI and the HA participants.

Contrast analysis was conducted to compare the percent of identification of the different modes in each of the groups. Table 3 presents the $F$ values obtained.

As can be seen in Table 3, the analyses revealed that all the groups showed significantly lower auditory scores than visual and auditory–visual scores. The auditory–visual score, however, was only better than the visual score for the hearing group. The auditory–visual and the visual scores were not significantly different for all groups of participants with hearing loss. The level of significance was set at .017, due to the three contrasts that were conducted (according to Bonferroni correction).

**Individual Results**

Examination of the individual identification scores of the participants in the four groups with regard to each of the three modes (auditory, visual, and auditory–visual) revealed great variations in the identification performance of all the participants in all modes. Nevertheless, although seven of the 10 participants in the NH group exhibited better auditory–visual performance in comparison to the performance of the visual mode, this was not the case in the three groups of participants with hearing loss. The three groups with hearing loss experienced greater variations. Although some performed better in the auditory–visual mode in comparison to the visual mode, others showed better performance in the visual mode in comparison to the auditory–visual mode, and there were also others who exhibited comparable performance in the two modes.

**Identification of Specific Emotions**

One-way ANOVAs with repeated measures were conducted for each of the six emotions. These analyses revealed a significant mode effect for each of the emotions: happiness, $F(2, 35) = 172.04$, $p < .001$; anger, $F(2, 35) = 92.19$, $p < .001$; surprise, $F(2, 35) = 116.61$, $p < .001$; sadness, $F(2, 35) = 29.72$, $p < .001$; fear, $F(2, 35) = 24.73$, $p < .001$; and disgust, $F(2, 35) = 86.39$, $p < .001$. There was a significant group effect for happiness, $F(3, 36) = 5.31$, $p < .01$; sadness, $F(3, 36) = 3.62$, $p < .05$; and disgust, $F(3, 36) = 4.91$, $p < .01$. Finally, there was a significant interaction between group and mode for happiness, $F(6, 70) = 4.53$, $p < .001$; anger, $F(6, 70) = 3.74$, $p < .01$; and disgust, $F(6, 70) = 2.74$, $p < .05$.

Table 4 presents the means and standard deviations for each of the emotions in the auditory mode.

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Early Implantees</th>
<th>Late Implantees</th>
<th>Hearing Aid Users</th>
<th>Normal Hearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happiness</td>
<td>114.22***</td>
<td>313.14**</td>
<td>125.51**</td>
<td>47.25**</td>
</tr>
<tr>
<td>Anger</td>
<td>113.26**</td>
<td>172.8**</td>
<td>346.17**</td>
<td>69.6**</td>
</tr>
<tr>
<td>Surprise</td>
<td>0.76</td>
<td>0.44</td>
<td>0.28</td>
<td>13.04***</td>
</tr>
<tr>
<td>Sadness</td>
<td>0.76</td>
<td>0.44</td>
<td>0.28</td>
<td>13.04***</td>
</tr>
<tr>
<td>Fear</td>
<td>0.76</td>
<td>0.44</td>
<td>0.28</td>
<td>13.04***</td>
</tr>
<tr>
<td>Disgust</td>
<td>0.76</td>
<td>0.44</td>
<td>0.28</td>
<td>13.04***</td>
</tr>
</tbody>
</table>

**Table 3** $F$ values and level of significance obtained in a comparison between the three modes of presentations in each of the research groups.
One-way ANOVAs were conducted in order to examine the differences between the groups with regard to the auditory mode, followed by multiple-contrast analyses for each emotion. The $F$ values obtained are presented in the table. It can be seen that there were significant differences in the auditory scores for each of the emotions, with the exception of surprise. All groups scored very low in the identification of surprise. The NH group scored better than all other groups in identifying happiness, sadness, and disgust. There were no significant differences in the scores of the other groups for these emotions. The NH group scored significantly better than the late-CI and the HA groups in identifying anger. However, there was no significant difference between the NH and early-CI groups in identifying this emotion. The early-CI group scored significantly better than the HA group. The NH group scored significantly better than the early-CI and late-CI group in identifying fear. There was no significant difference between the scores of the NH and the HA groups.

As can be seen in Table 4, the results of the auditory mode revealed a similar hierarchy in the perception of the different emotions by the NH and the two CI groups: Anger and sadness were identified the best and fear and surprise were perceived the least successfully. The HA group showed a different hierarchy than the other three groups.

One-way ANOVAs were conducted in order to examine the differences between the groups with regard to the visual mode, followed by multiple-contrast analyses for each emotion. These analyses revealed no significant differences between the groups with regard to each of the emotions. In general, emotion perception through the visual mode was comparable in the different groups. All the participants perceived happiness successfully ($M = 92.95\%$, $SD = 10.38$), then anger ($M = 89.44\%$, $SD = 11.9$), sadness ($M = 82.95\%$, $SD = 15.76$), and disgust ($M = 85.38\%$, $SD = 11.89$). The most difficult to identify were surprise ($M = 68.46\%$, $SD = 18.39$) and fear ($M = 54.02\%$, $SD = 24.41$).

One-way ANOVAs were conducted in order to examine the differences between the groups with regard to the auditory–visual mode, followed by multiple-contrast analyses for each emotion. These analyses revealed a significant difference with regard to the identification of surprise, $F(3, 36) = 3.49$, $p < .05$. The NH scored better than the late- and early-CI groups. The results of the HA group were not significantly different from those of any of the other groups. There were no significant differences between the different groups with regard to the perception of the other emotions. All the groups identified happiness best, then anger and then disgust. All participants with hearing loss had difficulties perceiving surprise. Fear was the most difficult for all the participants to identify.

A comparison between the correct identification of the different emotions in the three modes of presentation revealed a similar hierarchy between the visual and the auditory–visual modes. With regard to the auditory mode, the hierarchy was different. The principal difference was expressed in the perception of happiness and sadness. Happiness was the easiest to perceive when presented in the visual and the auditory–visual modes. On the other hand, it was more difficult to identify when presented in the

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### Table 4  Auditory percent identification (after correction for guessing; $M$ and $SD$) of the different emotions by the four groups and the obtained $F$ values

<table>
<thead>
<tr>
<th></th>
<th>Early implantees</th>
<th>Late implantees</th>
<th>Hearing aid users</th>
<th>Normal hearing</th>
<th>Group comparison, $F(3, 36)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Happiness</td>
<td>19.93 (13.47)</td>
<td>16.09 (15.14)</td>
<td>24.01 (17.17)</td>
<td>61.82 (20.3)</td>
<td>12.21***</td>
</tr>
<tr>
<td>Anger</td>
<td>47.9 (17.95)</td>
<td>33.97 (24.91)</td>
<td>15.97 (23.12)</td>
<td>61.7 (15.57)</td>
<td>6.08**</td>
</tr>
<tr>
<td>Surprise</td>
<td>9.96 (17.9)</td>
<td>–3.96 (17.19)</td>
<td>–1.96 (16.55)</td>
<td>11.04 (22.84)</td>
<td>1.34</td>
</tr>
<tr>
<td>Sadness</td>
<td>30.13 (25.25)</td>
<td>28.09 (28.52)</td>
<td>36.01 (29.09)</td>
<td>61.7 (25.3)</td>
<td>3.04*</td>
</tr>
<tr>
<td>Fear</td>
<td>1.92 (21.39)</td>
<td>6 (15.68)</td>
<td>15.97 (17.11)</td>
<td>38.06 (29.26)</td>
<td>4.87*</td>
</tr>
<tr>
<td>Disgust</td>
<td>19.93 (22.25)</td>
<td>15.97 (12.96)</td>
<td>7.92 (19.48)</td>
<td>54.5 (22.34)</td>
<td>8.78**</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01; ***p < .001.
auditory mode. Sadness was difficult to perceive when presented in the visual and auditory–visual modes but easier in the auditory mode.

Pearson correlations were conducted between the scores in the three modes for each of the four groups. There was a significant correlation between the visual and the auditory–visual scores for the early-CI group ($r = .82, p < .01$) and late-CI group ($r = .68, p < .05$) and in the NH group ($r = .88, p < .001$). There were no significant correlations between these modes for the HA group. There were no significant correlations between the auditory mode and the visual and auditory–visual modes for any of the groups.

Pearson correlations were also conducted between some demographic variables such as chronological age (for all participants), age of implantation and duration of implant use (for the participants with CI), degree of hearing loss (for the HA group), and age at onset of hearing loss (for all participants with hearing loss). A significant correlation was found only between the chronological age and the auditory–visual scores ($r = .45, p < .01$) and the visual scores ($r = .32, p < .05$). There were no significant correlations between the scores in the different modes and the other variables ($p > .05$).

Discussion

This study examined the ability of adolescents with and without hearing loss to perceive nonverbal emotional content solely through an auditory mode, solely through a visual mode, and through a combined auditory–visual mode. The performance of adolescents using HA was compared to the performance of two groups of adolescents using CI—those implanted early and those implanted at a later age.

Our first hypothesis that the auditory emotion perception of individuals with NH would be superior to that of all participants with hearing loss was supported. The auditory identification of emotions by the individuals with NH significantly surpassed that of all three groups of participants with hearing loss. This finding supported previous research on participants with NH and HA users (Most et al., 1993; Oster & Risberg, 1986; Rigo & Liberman, 1989; Shinall, 2005) and on CI users (Luo et al., 2007; Pereira, 2000; Peters, 2006).

We wanted to examine whether CI users would perform differently from HA users in auditory emotion perception. A comparison of the emotion identification patterns for the HA and CI users revealed that these groups performed comparably with regard to each of the presentation modes. Thus, the CI users did not demonstrate any advantage over the HA users in identifying emotions through either the auditory or the auditory–visual mode. It should be noted, however, that most of the CI users had a poorer unaided threshold of hearing than the HA users. It is possible that a CI advantage would have emerged if the two groups had comparable unaided thresholds; however, this possibility is difficult to pursue in future research because, currently, most implanted individuals have profound hearing loss. At this point, it is unknown whether the auditory or auditory–visual perception of emotions by CI users would exceed that of HA users matched for severity of hearing loss. Although the implant’s advantage in speech perception was demonstrated by previous studies, this relative benefit was mainly shown for the perception of segmental features (Calmels et al., 2004; Gestoettner et al., 2000).

The implant’s advantage in relation to the perception of suprasegmental features is not clear-cut. Some research has shown that perception of suprasegmental features improves after implantation (Huang, Wang, & Liu, 1995; Waltzman & Hochberg, 1990). Other studies, however, did not show an advantage for CI users compared to HA users (Boothroyd & Eran, 1994; Lee, van Hasselt, Chiu, & Cheung, 2002; Most & Peled, 2007; O’Halpin et al., 2006). Moreover, some of these studies even demonstrated poorer performance by CI users in comparison to HA users in the perception of intonation (Boothroyd & Eran, 1994; Most & Peled, 2007) and in the perception of syllable stress (Most & Peled, 2007). The authors attributed this poorer performance to many current implants’ inability to provide information on changes in the low-frequency range.

Inasmuch as the fundamental frequency is a very salient cue to the auditory perception of emotions (Murray & Arnott, 1993), it was expected that CI
users would experience difficulties in this perception in comparison to HA users. In contrast to expectations, despite the CI users’ lack of important sensory information, they did not demonstrate lower performance than the HA users. Perhaps the implant enabled enhanced auditory exposure to the verbal and social aspects of emotions in everyday life, and these improved skills may have compensated for the lack of sensory information required for emotion identification. In other words, the CI intervention process may have improved the linguistic and cognitive skills relevant to efficient emotion perception (De Sonneville et al., 2002). The findings of Gray, Hosie, Russell, Scott, and Hunter (2007) support this notion by demonstrating that the lack of verbal input in some deaf children slowed their development of emotional understanding.

Our hypothesis that the early-CI group would perform better than the late-CI group through the auditory and the auditory–visual modes was not supported. No significant differences emerged between the early and late implantees in any of the presentation modes, and no significant correlation emerged between the perception of emotions and age at implantation; however, the auditory perception results of the early implantees were slightly better than those of the late implantees. Moreover, the large standard deviations in both of these small groups, along with the very low perception levels suggesting a possible “floor effect,” may have precluded the emergence of significant differences in performance among these groups. Future research with larger samples in the different groups is recommended to further analyze this issue.

The results showing the implant’s lack of advantage over the HA and the insignificant correlation between age at implantation and auditory perception of emotions support the hypothesis that the current CI technology does not successfully transmit the acoustic information required for emotion perception.

All four study groups, including the hearing group, revealed comparable emotion perception through the visual mode. These results support previous reports of similarity in visual emotion perception by individuals with and without hearing loss (e.g., Dyck et al., 2004; Hosie et al., 1998; McCullough et al., 2005; Rollman & Harrison, 1996; Weisel, 1985). Other studies, however, reported lower visual identification of emotions by individuals with hearing loss (Bachara et al., 1980; Dyck & Denver, 2003; Most et al., 1993; Weisel & Bar-Lev, 1992). Future studies would do well to explore these inconsistencies in more detail, perhaps by administering a more sensitive measure such as response time, which may enable detection of possible subtle differences in the ability to perceive emotions through the visual mode (De Sonneville et al., 2002). Because the communication process is very dynamic, the time it takes to identify a facial expression in a real-life everyday situation might be revealing.

For participants with NH, auditory identification of emotions was significantly lower than visual identification or combined auditory–visual identification, as found in previous research (Burns & Beier, 1973; Hess et al., 1988; Most & Greenbank, 2000; Most et al., 1993; Rigo & Liberman, 1989; Wallbott & Scherer, 1986). Also supporting prior studies, and our hypothesis, participants with NH performance through the combined mode significantly surpassed that of each sensory mode alone (Most & Greenbank, 2000; Most et al., 1993). Although the difference between the visual and the combined modes was smaller than the difference between the auditory and the combined modes, participants with NH were able to utilize the auditory information and to benefit from the additional auditory information received about emotions in the combined mode.

In contrast to the participants with NH, who performed significantly better in the combined auditory–visual mode in comparison to either of the modes alone and who showed significantly superior perception of emotions through the visual mode in comparison to the auditory mode, all the groups of participants with hearing loss performed equally well in the combined auditory–visual mode and in the solely visual mode. In other words, the participants with hearing loss, whether they used HA or CI, were unable to benefit from the additional auditory information provided in the combined mode. In general, these groups were unable to use their residual hearing successfully. These results supported previous
results on individuals with HA (Most et al., 1993; Rigo & Liberman, 1989).

Examination of individual outcomes, however, revealed great variations. Seven of the 10 participants in the group with NH (70%) exhibited better auditory–visual scores in comparison to the solely visual scores, and the other three participants (30%) exhibited similar scores in those two modes. However, only 11 of the 30 participants with hearing loss (37%) benefited more from the auditory–visual mode than the visual alone, and four participants (13%) exhibited similar scores in those two modes. A full half of participants (15) even demonstrated better performance in the solely visual mode in comparison to the combined auditory–visual mode. This great discrepancy in the ability of individuals with hearing loss to integrate the information from the two sensory modes in the perception of speech was previously reported by Grant, Walden, and Seitz (1998).

Earlier results on implantees reported their successful integration of visual and auditory information when attempting to perceive words and sentences (Bergeson, Pisoni, & Davis, 2005; Lachs, Pisoni, & Kirk, 2001). The current findings indicating CI users’ inability to integrate different channels of information when perceiving emotions emphasizes the implant’s limitations in providing the auditory information necessary for emotion perception.

Age at implantation did not significantly affect participants’ emotion identification; however, it should be noted that, in this study, the earliest implantation age was 2.6 years. Schorr, Fox, Wassenhove, and Knudsen (2005) reported better auditory–visual integration in the speech perception of children who were implanted before age 2.6 years, in comparison to those who were implanted after this age. It is possible that participants who were implanted earlier might show better auditory–visual integration in the perception of emotions as well. Future studies should continue to examine emotion identification among participants with CI who were implanted at a younger age.

In addition to comparing the different groups of participants and the different modes of presentation, this study also investigated the hierarchy in accuracy of perceiving specific types of emotions. Results revealed differences in the ability to accurately perceive the various emotions through each of the presentation modes.

The NH and CI groups found anger and sadness the easiest to identify; fear and surprise were the most difficult, and happiness and disgust were in-between. A similar hierarchy was reported earlier (Most et al., 1993; Pereira, 2000; Sincoff & Rosenthal, 1985; Wallbott & Scherer, 1986).

The HA group revealed a similar pattern of results, with the exception of small differences in the ratings of anger and fear. The acoustic analysis performed on the stimuli was unable to account for these findings. Perhaps information on the voice quality of the speaker, in addition to the acoustic parameters of the fundamental frequency, the intensity, and the duration of the stimuli, is necessary in order to perceive some emotions better than others (Scherer, 1986).

A similar hierarchy of emotion types emerged for the visual and the auditory–visual modes, among all groups of participants, in line with previously reported results (Burns & Beier, 1973; Calder et al., 2000; Montagne et al., 2005; Most et al., 1993; Wagner et al., 1986). Happiness and anger were the easiest to perceive, then disgust and sadness, then surprise, and, finally, fear. This similarity of hierarchy in the visual and auditory–visual modes may suggest that visual information was more dominant in the combined mode.

Emotion perception in the three modes did not link significantly with implantation age, duration of implant use, or degree of hearing loss (for the HA users). However, participants’ chronological age did correlate significantly with emotion perception in the visual as well as the auditory–visual modes, with older participants obtaining better perception scores. This finding supports De Sonneville et al. (2002), who indicated that mental knowledge, which includes representation of the typical emotions, grows with age and results in a more effective emotion identification process. Also, Gray et al. (2007) reported that understanding of emotions developed among deaf children; those aged 9:5–13:2 years were better at assigning emotions to story characters than younger
deaf children aged 5:5–8:7 years. The participants in this study were between the ages of 10:0 and 17:6 years. Thus, the currently obtained correlation with chronological age suggests that the ability to perceive emotions continues to develop at a later age as well. This correlation might not have been expressed in relation to the auditory perception because of the very poor scores (aforementioned floor effect) for participants with hearing loss. Future research should continue to examine older participants in order to determine until what age this ability continues to develop.

Understanding of emotions by deaf children seems to improve with age (Gray et al., 2007); however, the present outcomes do not yet explicate possible sources of improvement over the years, such as increased understanding of emotional vocabulary or additional exposure to socioemotional situations. We used the inclusion criterion of a 75% score on an emotion vocabulary test for participation in the current study; therefore, we could not investigate the correlation between emotion vocabulary and emotion identification. Such a link has been found by other researchers like Nygaard and Queen (2008), who reported that listeners were faster in naming items when the tone of voice was congruent with the semantic content of the word. They demonstrated that the perception of spoken words was not independent of perception of the emotional prosody. Future research would do well to examine this relationship and its implications for developmental trajectories.

In light of the risks inherent in poor ability to perceive emotions, such as inadequate social patterns of behavior, poor social skills, and difficulties in social communication (Rieffe & Terwogt, 2000), further empirical inquiry should focus on whether children’s exposure to more opportunities for experiencing social–emotional situations and emotional tones at school and at home, with peers and adults, may possibly help them learn to recognize emotions better, and whether these skills may also be augmented through education. Dyck and Denver (2003) reported on improvement in the visual perception of emotion following intervention. Further research in this direction has important implications for intervention planning in order to help individuals with hearing loss to communicate better, with ramifications for social understanding and functioning.

In summary, based on the visual and the auditory–visual results, it can be assumed that the speaker’s mental state is intelligible to individuals with hearing loss in many communication interactions where the listener not only watches the speaker’s face but also listens to him/her. Nevertheless, in situations with inadequate or unavailable visual information, such as communication on the telephone, in the car, or in the dark, the listener needs to rely on the auditory information provided.

The findings of this study question the benefits of CI in transmitting the acoustic information required to identify the speaker’s emotional state. The current outcomes highlight the importance of incorporating nonverbal aspects of communication, including emotion perception, into the intervention process for individuals with hearing loss wearing HA or CI. Specific attention should be paid to the auditory perception of emotions when visual input is missing.

In addition, research should continue to examine the effects of current CI coding strategies, which claim to provide better information in the low-frequency range with regard to the ability to perceive emotions. For example, the fine structure processing (FSP) strategy recently offered by Med-El claims to provide periodicity information. Mitterbacher, Zierohofer, Schatzer, and Kals (2005) reported improved pitch discrimination with the FSP strategy in comparison to the Continuous Interleaved Sampling strategy. Future studies should also continue to research participants who use CI on one ear and HA on the other, in order to determine whether this bimodal condition results in better emotion perception when compared to the use of CI alone. Examination of children with bilateral CI is recommended as well. And finally, future examination of emotion perception by postlingually deafened individuals in comparison to prelingually deafened individuals would allow researchers to evaluate the effect of auditory and linguistic exposures on the ability to perceive emotions.
### Appendix A: Early implantees

<table>
<thead>
<tr>
<th>Participant no.</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Age of implantation (years)</th>
<th>Implant usage duration (years)</th>
<th>Implant type</th>
<th>Speech processor type</th>
<th>Implanted ear</th>
<th>PTA Rt/Lt (dB)</th>
<th>Cause of hearing loss</th>
<th>Age at discovery (years)</th>
<th>Age at rehabilitation (years)</th>
<th>Parents are HH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>11</td>
<td>4:1</td>
<td>6:9</td>
<td>Nucleus24</td>
<td>Sprint</td>
<td>Left</td>
<td>108/NR</td>
<td>Genetic</td>
<td>0:1</td>
<td>0:3</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>14:4</td>
<td>3:1</td>
<td>11:3</td>
<td>Nucleus22</td>
<td>Sprint</td>
<td>Right</td>
<td>110/102</td>
<td>UK</td>
<td>0:6</td>
<td>1</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>15:7</td>
<td>2:6</td>
<td>13:1</td>
<td>Nucleus22</td>
<td>Sprint</td>
<td>Left</td>
<td>117/113</td>
<td>UK</td>
<td>1:5</td>
<td>1:8</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>13:10</td>
<td>5:2</td>
<td>8:8</td>
<td>Clarion</td>
<td>S-Series</td>
<td>Right</td>
<td>115/95</td>
<td>UK</td>
<td>1:8</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>10:10</td>
<td>2:6</td>
<td>8:4</td>
<td>Clarion</td>
<td>S-Series</td>
<td>Right</td>
<td>NR/97</td>
<td>Meningitis</td>
<td>1:6</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>15</td>
<td>5:6</td>
<td>9:6</td>
<td>Clarion90k</td>
<td>Auria</td>
<td>Left</td>
<td>100/NR</td>
<td>UK</td>
<td>1</td>
<td>1:6</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>13:3</td>
<td>6</td>
<td>7:3</td>
<td>Nucleus24</td>
<td>Sprint</td>
<td>Right</td>
<td>NR/88</td>
<td>Genetic</td>
<td>0:1</td>
<td>0:3</td>
<td>No</td>
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<td>8</td>
<td>F</td>
<td>13</td>
<td>3:11</td>
<td>9:1</td>
<td>Nucleus24</td>
<td>Sprint</td>
<td>Right</td>
<td>118/110</td>
<td>UK</td>
<td>0:8</td>
<td>1:5</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>13:7</td>
<td>2:6</td>
<td>11:1</td>
<td>Nucleus22</td>
<td>Sprint</td>
<td>Left</td>
<td>115/NR</td>
<td>Genetic</td>
<td>0:2</td>
<td>0:3</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>14:11</td>
<td>4</td>
<td>10:11</td>
<td>Nucleus22</td>
<td>Sprint</td>
<td>Left</td>
<td>113/NR</td>
<td>Genetic</td>
<td>0:7</td>
<td>1</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: F = female; HH = hard of hearing; M = male; UK = unknown etiology.

*Pure tone average—means at 500, 1,000, and 2,000 Hz.

### Appendix B: Late implantees

<table>
<thead>
<tr>
<th>Participant no.</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Age of implantation (years)</th>
<th>Implant usage duration (years)</th>
<th>Implant type</th>
<th>Speech processor type</th>
<th>Implanted ear</th>
<th>PTA Rt/Lt (dB)*</th>
<th>Cause of hearing loss</th>
<th>Age at discovery (years)</th>
<th>Age at rehabilitation (years)</th>
<th>Parents are HH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>16:2</td>
<td>6:2</td>
<td>10</td>
<td>Clarion90k</td>
<td>Auria</td>
<td>Left</td>
<td>113/NR</td>
<td>UK</td>
<td>3</td>
<td>3:6</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>15:6</td>
<td>12</td>
<td>3:6</td>
<td>Nucleus24</td>
<td>3G</td>
<td>Left</td>
<td>105/102</td>
<td>UK</td>
<td>0:6</td>
<td>0:9</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>13:8</td>
<td>6:11</td>
<td>6:9</td>
<td>Nucleus24</td>
<td>Sprint</td>
<td>Left</td>
<td>95/115</td>
<td>Genetic</td>
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<td>0:3</td>
<td>Yes</td>
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<td>4</td>
<td>M</td>
<td>17:6</td>
<td>15</td>
<td>2:6</td>
<td>Clarion90k</td>
<td>Auria</td>
<td>Right</td>
<td>105/110</td>
<td>Genetic</td>
<td>1:10</td>
<td>2:3</td>
<td>No</td>
</tr>
<tr>
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<td>F</td>
<td>10</td>
<td>8:3</td>
<td>1:9</td>
<td>Pulsar</td>
<td>Tempo+</td>
<td>Right</td>
<td>103/102</td>
<td>Genetic</td>
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<td>No</td>
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<td>F</td>
<td>14:8</td>
<td>12:6</td>
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<td>Nucleus24</td>
<td>3G</td>
<td>Right</td>
<td>NR/122</td>
<td>UK</td>
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<td>M</td>
<td>17:3</td>
<td>11:11</td>
<td>5:4</td>
<td>Nucleus24</td>
<td>3G</td>
<td>Left</td>
<td>105/NR</td>
<td>UK</td>
<td>0:8</td>
<td>1:6</td>
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</tr>
<tr>
<td>8</td>
<td>F</td>
<td>17</td>
<td>16</td>
<td>1</td>
<td>Freedom</td>
<td>Freedom</td>
<td>Right</td>
<td>107/105</td>
<td>UK</td>
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</tr>
<tr>
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<td>F</td>
<td>17:5</td>
<td>16:2</td>
<td>1:3</td>
<td>Freedom</td>
<td>Freedom</td>
<td>Right</td>
<td>102/92</td>
<td>CMV</td>
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<td>3</td>
<td>Nucleus24</td>
<td>3G</td>
<td>Left</td>
<td>88/NR</td>
<td>UK</td>
<td>2:6</td>
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<td>No</td>
</tr>
</tbody>
</table>

Note: CMV = cytomegalovirus; F = female; HH = hard of hearing; M = male; UK = unknown etiology.

*Pure tone average—means at 500, 1,000, and 2,000 Hz.
### Appendix C: Hearing Aid users

<table>
<thead>
<tr>
<th>Participant no.</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Hearing aid type</th>
<th>PTA Rt/Lt hearing aid (dB)</th>
<th>PTA with hearing aid (dB)</th>
<th>Cause of hearing loss</th>
<th>Age at discovery (years)</th>
<th>Age at rehabilitation (years)</th>
<th>Parents</th>
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<tbody>
<tr>
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<td>F</td>
<td>14:9</td>
<td>Widex</td>
<td>88/97/30</td>
<td>88/97/30</td>
<td>UK</td>
<td>3:6</td>
<td>5:2</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>12:11</td>
<td>Siemens</td>
<td>97/98/50</td>
<td>97/98/50</td>
<td>UK</td>
<td>2</td>
<td>3:10</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>10:2</td>
<td>Siemens</td>
<td>80/85/33</td>
<td>80/85/33</td>
<td>CMV</td>
<td>1:8</td>
<td>2:4</td>
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</tr>
<tr>
<td>4</td>
<td>F</td>
<td>15:3</td>
<td>Oticon</td>
<td>80/75/33</td>
<td>80/75/33</td>
<td>UK</td>
<td>3</td>
<td>3:7</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>12:11</td>
<td>Phonak</td>
<td>73/73/28</td>
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<td>1</td>
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<td>No</td>
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<td>6</td>
<td>M</td>
<td>15</td>
<td>Siemens</td>
<td>75/110/25</td>
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<td>0:3</td>
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<td>M</td>
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<td>Widex</td>
<td>107/95/32</td>
<td>107/95/32</td>
<td>Genetic</td>
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<td>0:6</td>
<td>Yes</td>
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<td>8</td>
<td>M</td>
<td>15</td>
<td>Widex</td>
<td>88/93/25</td>
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<td>3:5</td>
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<td>Phonak</td>
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</tr>
</tbody>
</table>

Note: F = female; HH = hard of hearing; M = male.

*Pure tone average—means at 500, 1,000, and 2,000 Hz.*

### References


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