MARTA WYSOCKA*, LUIZA MACKIEWICZ**
*Maria Curie-Skłodowska University, Lublin
Department of Logopedics and Applied Linguistics
**Center for Comprehensive Psychological-Pedagogical Therapy
for Children "SPEKTRUM", Grodzisk Mazowiecki

Music and Intonation in the Perception of Children Using Hearing Aids

SUMMARY

The features shared by speech and music are particularly noticeable in prosody. The results of studies on the connections between perception processes of the two phenomena, although important from the perspective of the use of music in measures serving to shape the prosody of speech, are described comparatively seldom in literature. There are also few reports concerning persons with impaired hearing.

The article presents the results of the authors' own research on the perception of musical phenomena – melody and rhythm as well as intonation in speech by prelingual hearing-impaired children with hearing aids. As compared with the control group, the results show a lower perception skill of the subjects in respect of all these phenomena. The weakest disorders are reported in the perception of intonation structures, while the strongest – in the perception of instrumental melodies
Key words: perception of prosody and music, impaired hearing, hearing aids

INTRODUCTION

The prosodic organization of speech resembles music in many respects. In most publications, the phenomenon shown as being shared by prosody and music is melody termed in speech as intonation, stress and rhythm. Studies in the evolution of linguistic and musical behaviors in human phylogeny point to very early beginnings of relations between prosody and music (Patel 2006). Also the studies on the connections between musical and prosodic competence in ontogeny provide ample evidence for interrelationships between the level of developed skills in the perception of prosodic features and phenomena, and music (*inter alia* Saffran et al. 1999; Palmer et al. 2001; Wysocka 2012). Interrelations are also pointed out between musical abilities and linguistic processes associated with phonological awareness, and the ability to read with understanding (Anvari et al. 2002), as well as the positive effect of musical training on the development of linguistic competence (Schön et al. 2004; Magne et al. 2006).

The studies, described in literature, on the relations between the perception of prosody and music are usually conducted with biologically normal children and adults or with individuals with impairments of the central nervous system. There are few reports on the subject that concern persons with impaired hearing. There are, admittedly, some publications on speech prosody perception by individuals with hearing loss, mainly with cochlear implants (Luo et al. 2007; Chatterjee, Peng 2008; Hopyan-Misakyan et al. 2009; Meister et al. 2009; Nakata et al. 2012; Geers et al. 2013; Van Zyl, Hanekom 2013; Volkova et al. 2013; Fuller et al. 2014; Gaudrain, Başkent 2015; Kalathottukaren et al. 2017), however, the presentation of relationships between these processes is rare in literature (Wang et al. 2011; See et al. 2013; Torppa et al. 2014; Gfeller 2016).

The aim of the present article is to present the results of the authors' studies (i.e. tests) conducted in a nine-child group aged 6–11 years, with bilateral, prelingual hearing impairments, and using hearing aids. The research is concerned with the perception of intonation in speech and musical phenomena: instrumental melodies and rhythmic structures, and the mutual connections between these processes.

PERCEPTION OF PROSODY

Many scholars point out the fact that what patients with hearing loss find most difficult to perceive is phenomena based on temporal changes in basic frequency (cf. the survey of studies in: Wysocka, Mackiewicz 2016). These include intonation, phrasal stress (in which the pitch component is very strong), tone patterns in tonal languages, and emotional prosody. The cause of this state are difficulties in the auditory frequency processing and the specificity of the function of auditory prostheses, which enable good perception of volume changes and their temporal organization, but far worse perception of frequency changes. Studies show that if the foregoing prosodic phenomena are also accompanied by distinct changes in duration and volume, e.g. a stressed syllable stands out from the others not only by its pitch but also by its length and volume, these phenomena are easier to perceive (Most 2000).

Literature does not show conclusive evidence concerning the influence of the time of prosthesis placement and the duration of wearing auditory prostheses on the development of prosodic skills (Chatterjee, Peng 2008; Peng et al. 2008; Lenden, Flipsen 2007; Wang et al. 2011). According to R. See et al. (2013), progression in acquiring them can be observed in the 0–7 years after implantations (the patients then displayed an increased accuracy in identifying the rising intonation). After that period, no significant development of perception skills in this field were reported, which may suggest that the distortion of features of a speech signal by the auditory prosthesis makes it possible to acquire these skills only to a certain degree. However, emphasis is laid on early and intensive treatment, which largely influences the development of the perception of prosodic features (Most, Peled 2007).

Another issue, important in the discussion on the perception of prosody by hearing-impaired people is the influence of the kind of auditory prostheses (cochlear implant or hearing aid) on the ability to perceive prosodic structures. In many studies, the users of hearing aids and cochlear implants are members of the same group of subjects, and their results are compared exclusively with the results of the normally hearing control group (e.g. Kalathottukaren et al. 2017). There are few comparative studies on the perception by individuals with hearing aids and cochlear implants, and these are connected with different stages of the development of technologies of auditory prostheses. Some scholars demonstrate that patients with cochlear implants perceive changes in basic frequency and other suprasegmental features better than those with hearing aids (Waltzman, Hochberg 1990), whilst others show that more advanced processors hinder a full perception of prosodic phenomena, which are better perceived by hearing aid users (Green et al. 2004). Such studies also include those carried out by T. Most and M. Peled (2007), who studied speech prosody perception in the groups of children with prelingual hearing impairment and with severe and profound hearing loss, who wore cochlear implants and hearing aids. The two scholars assessed the perception of phrasal stress, lexical stress, and intonation. The results did not show the presupposed advantage of children with cochlear implants regarding the correctness of the performed tasks. In all groups, intonation and phrasal stress were best perceived, the perception of lexical stress being the worst. The best results were obtained by the children with severe hearing loss who used hearing aids, the second best – by the children with profound hearing loss – hearing aid users. The children with cochlear implants achieved the lowest results.

Summing up the available results of studies on prosody perception by hearing-impaired children, it should be said that most problems are reported in the perception of phenomena in which the leading role is played by changes in the duration of basic frequency of speech signal. On the basis of the available publications it is difficult to formulate conclusive statements on the effect of the kind of auditory prosthesis on effective prosodic perception. This question is additionally complicated by the fact that in studies on the speech prosody in children with hearing impairment a high discrepancy between results is reported in groups which were intended to satisfy the condition for uniformity in terms of the time when a hearing impairment arose, the time of prosthesis placement, the kind of prosthesis, and the degree of the severity of hearing loss (Peng et al. 2008; Chin et al. 2012).

PERCEPTION OF MUSIC

The perception of music by hearing aid users is influenced by many factors. These include: characteristics of the input signal, how a hearing aid processes sounds, the functioning of peripheral hearing and central processes of auditory processing, and personal musical experience (Chasin, Hockley 2014).

It should be stressed that the main objective of hearing aids is to amplify speech signal features because disordered speech perception and the consequent communication disorders are the greatest problem faced by persons with impaired hearing and by their families (Chasin, Hockley 2014). This specification is not, regrettably, conducive to the perception of music sounds, which differ from speech sounds in some ways. A significant difference consists in that the spectral structure of music sounds is characterized by far greater variability in time than speech sounds, which is not fully transmitted by hearing aids. Another aspect of the functioning of these devices that affects the perception of music is different input levels of sound pressure for speech and music. The most sonorous and intense elements of speech signal – vowels – do not exceed the 85 dB SPL level, while the most intensive musical sounds reach the 100–110 dB SPL range, and sporadically even 118 dB SPL. The level of peak limit of the input signal, being generally set in hearing aids at ca. 85 dB SPL and allowing the users to exactly process even the peak speech level, nevertheless limits the perception of music and causes diverse kinds of distortions (Chasin 2003).

To sum up, in the perception of hearing-impaired individuals with hearing aids, musical sounds may be distorted because of the hearing defect itself but also due to the imperfect construction of hearing aids in terms of adjustment to the characteristics of musical sounds. It should be added, however, that in recent years, taking the foregoing difficulties into account, hearing aid producers have tried to develop and improve the functions of these devices in order to enhance the perception of music.

Studies on the perception of music by hearing-impaired people show that they relatively well perceive rhythmic structures or the phenomena that require time processing. They cope far worse with perceiving musical phenomena based on changes in sound pitch and tone (melody, harmonic consonance, recognition of instruments or voices of signers) (Xu et al. 2009; Gfeller et al. 2011; Wang et al. 2011; Hsiao, Gfeller 2012; Innes-Brown et al. 2013).

Many studies on the perception of music by hearing-impaired children focus on estimating their ability to recognize familiar melodies (e.g. Hsiao 2008; Olszewski et al. 2005; Trehub et al. 2009). Their results show that the accuracy of melody identification increases when the perception of melodic structures can be assisted by musical rhythm and the text present in the material used in the tasks.

Only in very few studies on the perception of music by children with hearing loss, short melodies, composed for the purpose, were used as stimuli (Vongpaisal et al. 2006; See et al. 2013). The usefulness of such studies in the discussion on the development of the processes of musical structure perception is related to the fact that they do not require the child to be previously familiar with a specific repertory of musical pieces. Furthermore, they make it possible to prevent characteristic, easily recognizable rhythmic or melodic structures present in some pieces for children from influencing the study results. On the other hand, they enable testing the ability to perceive the phenomena important for music, such as melodic contours, and to discern and define the character of pitch changes in melodic structures.

PROSODY AND MUSIC

Despite a large number of publications devoted to the perception of speech prosody and music perception in cases of hearing impairments, those that concern the interconnections of these processes are rare (Wang et al. 2011; See et al. 2013; Torppa et al. 2014; Gfeller 2016).

The results of studies closely similar to those presented in our article were published in 2013 (See et al.). They were concerned with perception of intonation and melodies sung by children with cochlear implants, or, more precisely, with how they recognize rising and falling melodic and intonation contours. The authors of the 2013 study showed that children with cochlear implants find it more difficult than their normal hearing peers to identify both intonation and melodic contours. The level of correct answers in intonation and melody perception tasks was comparable in individual groups. In intonation and melody perception tasks, children with cochlear implants scored 63.1 % and 61.6%, while the hearing children – 82.1% and 84.2%. Better mean results are, therefore, characteristic of intonation contours although the advantage is negligible. Children with cochlear implants, however, recognized rising contours with greater accuracy in melody than in intonation. The scholars attribute this result to the fact that greater pitch changes in the musical material than in speech made it easier for the subjects to recognize rising melodic contours. It was also found that greater pitch differences in intonation contours were helpful in rising intonation identification. The authors come to conclusion that the musical material based on higher differences in pitch intervals than those in question may prove helpful in molding the perception of intonation structures. No significant statistical influence of variables of the subject's age and the duration of the cochlear implant use on the obtained results was demonstrated, which may suggest that perception abilities in the perception of intonation and sung melodies do not develop dynamically with the duration of wearing the cochlear implant because of distortions of the signal features. Only an increase in the accuracy of recognition of rising intonation was observed in the 0–7 year range after implantation.

The existence of relationships between the proficiency in perceiving prosodic and musical phenomena in hearing-impaired persons justifies the use of musical training in their treatment. The data in literature allow a conclusion that musical training conducted with persons with hearing loss may increase their competence in speech perception, particularly in prosody. Scholars succeeded in improving phrasal stress perception, discriminating between pitch and volume in speech as well as auditory memory, which, they believe, strongly influences prosody perception (Yucel et al. 2009; Torppa et al. 2014).

It should be stressed that an increase in the number of studies on the characteristics of connections between the mechanisms of music and prosody perception could contribute to greater rationalization of measures used in the abovementioned musical training and improvement of its efficacy.

METHOD AND MATERIAL

The objective of our study is to assess perception skills of 6 to 11-year-old children with prelingual hearing impairment in perceiving intonation and musical phenomena – melodic and rhythmic structures. The authors' diagnostic tool (Wysocka 2012) was applied, from which the tasks enabling assessment of the phenomena in question were selected.

When testing the ability to perceive intonation, two- and seven-syllable structures were used: the *tata* [daddy] and the utterance: *teraz idziesz do domu* [now you're going home]. The two-syllable intonation structure of the word had three realizational intonation variants: the rising, falling, and even contours, while the seven-syllable structure had six variants showing a falling contour, a rising contour (in two variants), falling-rising (in two variants), and a rising-falling contour. Each of the realization variants had its equivalent in the testing material, realized exclusively by means of vowels, excluding the consonantal segments of the word and sentence (realization of *aa* for the word, and *ea ie oou* for the sentence). This measure was taken in order to eliminate lexical meaning from the stimuli.

The vowel structures were characterized by F_0 values very close to vowels found in whole-segmental structures. The basic frequency of vowels used throughout the whole material usually ranges from 170 to 500 Hz (the mean value of F_0 being 270.19 Hz).

In order to eliminate the influence of changes in the temporal and rhythmic organization on the perception of intonation, the structures within a given group (different intonation variants of the word and their vowel equivalents, and utterance variants and their vowel equivalents) were realized at the same rate, preserving the constant place of lexical stress for particular variants.

The assessment of the perception of musical phenomena was conducted using melodic and rhythmic structures. The melodic structures contained from two to seven elements (musical pitches $d_1 – a_1$, and F_0 values from 293.66 to 440.00 Hz). They were realized by means of quarter notes at a moderate rate, without auditorily observable differences in volume. Like in intonation structures, changes in pitch had rising, falling, falling-rising or rising-falling contours. To assess the perception of rhythm, one-bar rhythmic structures were utilized, containing quarter notes and quavers organized in the 4/4 meter at a moderate rate.[1]

The test material was previously recorded and saved in the *.wav. format. The tests used the tasks of stimuli discrimination, given in pairs (for all the phenomena tested), and the tasks of identifying the directions of pitch changes (in melodic and intonation structures). In the discrimination tasks, the subject decided whether the presented stimuli were the same or different, in the identification tasks – whether the sound pitch rose or fell with time (rising and falling intonation contours and melodies were utilized in them).

The tested group consisted of nine six-to-eleven-year-old children (the mean age – 8.4, the average auditory age – 6.1) with bilateral hearing impairment acquired in the prelingual periods, who have used hearing aids since one year of age (2 children), since two years of age (one child), since three (five children) and since seven years of age (one child). All the children are brought up by hearing parents.

The tests were conducted during individual sessions. The material was presented in a free auditory field. The subjects were seated 1.5 meter away from the audio speakers, in the position enabling the signal to reach both ears simultaneously. The test proper was preceded by the explanation of the procedure and trial exposition. The test material was repeated if necessary: at the request of the tested child or when the subject's lack of concentration during presentation was observed.

In order to determine the degree of development of the perception of prosodic and musical phenomena in the tested children, their percentage scores were com-

[1] A detailed description of the tool can be found in the publication *Prozodia mowy w percepcji dzieci* (Wysocka 2012).

pared with the results of the group of ten hearing six-year-old children tested with the same tool and according to the same procedure (results of the hearing children cited after: Wysocka 2012).

RESULTS

The mean of results obtained in individual types of tasks and the standard deviation values are presented in Figure 1. Differences between the groups in the results scored by the tested children are noticeable particularly in discrimination tasks.

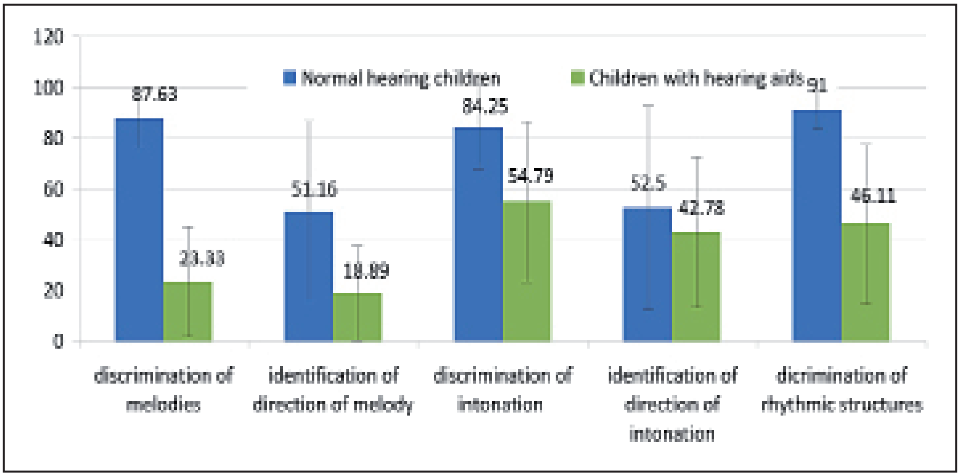

Figure 1. The arithmetical mean of the results scored by the tested prelingually hearing-impaired children with hearing aids and by hearing six-year-old children in tasks of melody, intonation and rhythm perception (%)

Source: Own elaboration.

The test results show a significant individual diversification in the level of prosody perception performance of hearing-impaired children (cf. Table 1), which confirms the reports in previous publications (Peng 2008; Chin 2012). All tasks are characterized by a very strong and strong intra-group diversification of the obtained results. In the group of hearing children a very strong diversification was observed only in the tasks of determining the direction of pitch changes, which is related to the fact that this skill is not yet widespread at this age (cf. Wysocka 2012).

The hearing children better discriminate between all the stimuli. There were no statistically significant differences between the results of hearing children and the results of hearing-impaired children only in the tasks of discriminating the intonation of a seven-syllable utterance. In turn, in the tasks of identifying the

Table 1. Intra-group diversification of the results of particular task types (%)

Children with hearing aids	Melodies		Intonation		Rhythmic structures
	Discrimination	Identification	Discrimination	Identification	Discrimination
Variation coefficient	92.31***	98.65***	57.71**	69.03***	68.10***
Standard deviation	21.54	18.63	31.62	29.53	31.40
Mean	23.33	18.89	54.79	42.78	46.11
Modal value	10.00	0.00	100.00	20.00	75.00
Normal hearing children	Melodies		Intonation		Rhythmic structures
	Discrimination	Identification	Discrimination	Identification	Discrimination
Variation coefficient	12.94*	69.17***	19.36*	76.53***	8.11*
Standard deviation	11.34	35.39	16.31	40.18	7.38
Mean	87.63	51.16	84.25	52.50	91.00
Modal value	96.60	0.00	100.00	0.00	95.00

Variation coefficient: diversification: weak*, strong**, very strong***
Source: Own elaboration.

direction of changes in pitch in melody and intonation, a high level of significant differences was reported only in those tasks in which musical stimuli were used (cf. Table 2).

The earlier publications presenting the results of studies on the perception of music by children with hearing aids and cochlear implants showed the advantage of their abilities to perceive rhythmic structures over melodic ones (Innes-Brown et al. 2013). This phenomenon also appeared in our own studies presented in this paper. Worth noting is also the fact that in the group of children using hearing aids the lowest results – out of all discrimination tasks – were reported in melodic tasks (mean 23.33%, modal value 10.00%; cf. Table 1). Even lower results were obtained by the hearing-impaired children in the tasks of identifying the direction of the contours of melodic structures (mean 18.89%, modal value 0.00%). This shows special difficulties of the tested children with hearing aids in processing the pitches of musical sounds and their changes.

Table 2. Statistical dependencies between the results of children with hearing aids and hearing children in respective task types (Mann–Whitney U test)

	Discrimination tasks		Identification tasks	
	Level of significance	Effect size	Level of significance	Effect size
Melodies	p < 0.001***	r = -0.844	p = 0.026*	r = -0.693
Intonation of a two-syllable word	p = 0.004**	r = -0.669	p = 0.834	r = -0.048
Intonation of vowels in a two-syllable word	p = 0.029*	r = -0.501	p = 0.302	r = -0.237
Intonation of a seven-syllable utterance	p = 0.063	r = -0.426	p = 0.649	r = -0.104
Intonation of vowels in a seven-syllable utterance	p = 0.013*	r = -0.571	p = 0.363	r = -0.209
Rhythmic structures	p < 0.001***	r = -0.829		

* statistically significant difference at $p < 0.05$, ** statistically significant difference at $p < 0.01$, *** statistically significant difference at $p < 0.001$

Source: Own elaboration.

Higher results were reported in intonation tasks than in melodic ones. This fact was influenced without doubt by the specificity of hearing aids whose purpose is first of all to amplify speech signals. This can be also explained by the more frequent exposure of the subjects to speech than music in their daily life and by a greater frequency of the children's realization of these structures. Better perception of the structures may have been also determined by greater differences of basic frequency in intonation contours than in melodic contours, which, in all likelihood, facilitated executing the tasks of identifying the direction of changes in voice pitch. The factor of compensatory support of intonation perception by temporal and rhythmic organization, whose importance to hearing-impaired persons is emphasized by some scholars (Stickney et al. 2004; Green et al. 2004; 2005), should be excluded in the case of the tests described here because the test material was standardized in this respect. The same rhythmic/stress structure and the same rate were characteristic of individual realizations of the words used in the tests, utterances, and their vowel equivalents, which caused the subjects to follow changes in the sound pitch only while they performed the tasks.

The analysis of the correctness of answers in the tasks of discrimination of melodic structures depending on the number of constituent elements leads to the conclusion that the growing number of elements and the consequent prolonged duration of a structure reduce the accuracy of answers, both in discrimination and identification tasks (Figure 2).

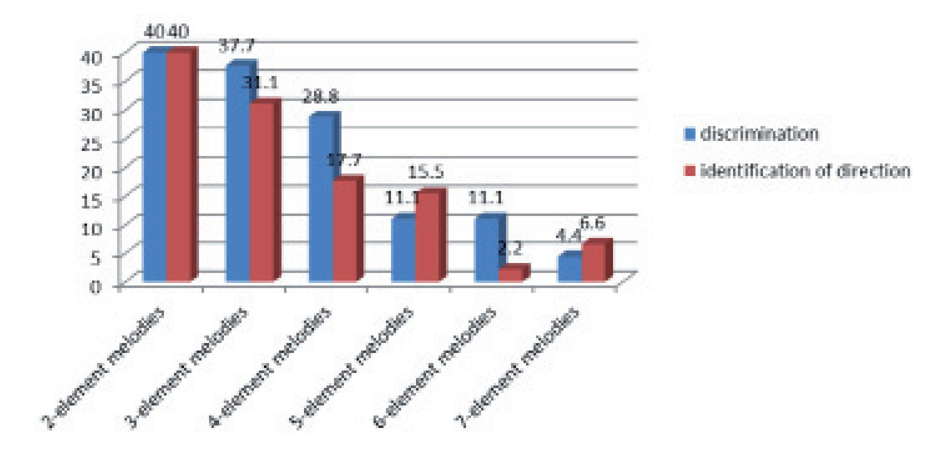

Figure 2. The arithmetical mean of the results scored by the tested, prelingually hearing-impaired children in tasks of melodic discrimination and identification of direction of their changes (%)
Source: Own elaboration.

A similar tendency appears in the tasks of discrimination and identification of intonation structures (Figure 3), which proves that as the number of elements increases, difficulties in the perception of these structures grow, being caused by the need to substantially engage auditory short-term memory. It should be added that the tendency for the declining accuracy of answers with the growing number of elements is found also in hearing children (Wysocka 2012).

Another factor that caused a decrease in the number of correct answers in intonation tasks was the elimination of full-segmental structure from the stimuli, and, consequently, of lexical meaning. The stimuli, in which only vowels were used, i.e. they were devoid of semantic value, were perceived worse in discrimination and identification tasks. Higher correctness of answers is characteristic of discrimination tasks although they require retaining two structures in auditory short-term memory for comparison. The tasks identifying the direction of pitch changes in melody and intonation, although they encumbered auditory memory to a lesser extent, turned out to be more difficult for the subjects (cf. Figure 1). The results of earlier studies on prosodic and musical perception (Wysocka 2012) lead to the conclusion that this phenomenon is also found in hearing children, its intensity being inversely proportional to their age. It is, therefore, characteristic of the early stages of prosodic and musical development, found in biologically normal children before the operational stage of thinking (cf. Wysocka 2012).

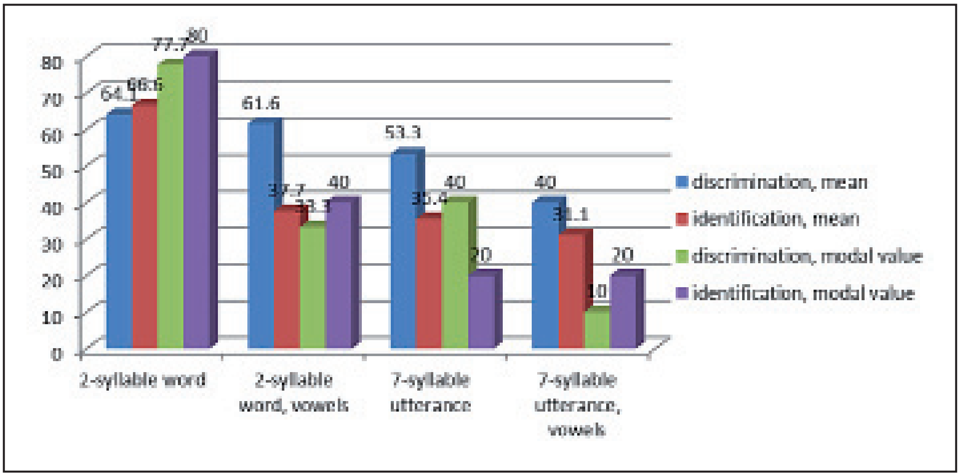

Figure 3. The arithmetical mean and modal value of the results scored by the tested prelingually hearing-impaired children with hearing aids in tasks of intonation discrimination and identification of direction of their changes (%)

Source: Own elaboration

CONCLUSIONS

The reason for conducting comparative studies on the mechanisms of musical and prosodic perception is many similarities occurring between these phenomena. The importance of the studies rises because of therapeutic measures in which musical material is used to improve auditory and speech functions. Such procedures are also used with hearing-impaired children, therefore, it is in order to ask a question about their abilities to perceive musical phenomena. The answer to the question rationalizes therapeutic objectives and enhances the efficacy of treatment.

The presented results of our studies on the perception of melody and rhythm as well as intonation in speech by prelingually hearing-impaired children with hearing aids lead to the conclusion that the specificity of the studied perception processes taking place in hearing-impaired children and hearing children is similar in some respects. The tendencies observed in the tested children with hearing loss (the advantage of results of discrimination tasks over identification tasks, the strong influence of the growing number of melodic structure elements, and the effect of the absence of full-segmental structure from intonation structures on the declining correctness of answers) are also characteristic of hearing children, mainly in the preoperational stage of thinking (cf. Wysocka 2012). It should, however, be stressed that the level of development of the competencies in question is far lower in children with hearing loss than in hearing children.

Children with hearing impairment best perceive intonation structures, slightly worse – rhythmic sequences, while their perception of instrumental melodies is most distorted. The obtained results confirm the conclusions from other publications cited in the present study, concerning the advantage of temporal processing over frequency processing in hearing-impaired individuals. This advantage is visible particularly in musical tasks, but the results of intonation tasks, although the highest in the group of children with hearing loss, also differ from those achieved by hearing children, which shows difficulties of the tested hearing-impaired children in perceiving changes in voice pitch. Disorders in the perception of temporal changes in basic frequency have consequences not only in the form of disturbances of intonation perception but also of other prosodic phenomena important in communication – phrasal stress or emotional prosody. It appears, therefore, that the enhancement of perception of changes in basic frequency, both in speech signal and music, should occupy an important position in therapeutic treatment.

In view of the presented results of our own studies, several therapeutic recommendations can be proposed which would enhance the efficacy of therapeutic treatment serving to mold intonation perception, using instrumental melodic structures.

1. In the case of great difficulties in the perception of instrumental music, the use of melodic structures to mold intonation perception may prove ineffective.
2. In the procedure, meant to mold the perception of intonation and melody, it is necessary to take into account the principle of gradation of difficulty: the use of structures consisting of a smaller number of elements at the early stages of treatment. A necessary element of the treatment should be auditory short-term memory exercises.
3. Exercises in identifying the features of melodic and intonation structures should be preceded by exercises in their discrimination as these are easier for hearing-children with hearing impairment.
4. In the measures serving to mold the perception of intonation structures, those that will be easier are phrases with a complete segmental structure, i.e. words, groups of words, or utterances with specific meaning.

BIBLIOGRAPHY

Anvari, S.H., Trainor, L.J., Woodside, J., Levy, B.A., 2002, *Relations among Musical Skills, Phonological Processing, and Early Reading Ability in Preschool Children*, "Journal of Experimantal Child Psychology", 83, 111–130.

Chasin, M., 2003, *Music and Hearing Aids*, "The Hearing Journal", 56(7), 36–41.

Chasin, M., Hockley, N.S., 2014, *Some Characteristics of Amplified Music Through Hearing Aids*, "Hearing Research", 308, 2–12.

Chatterjee, M., Peng, S.C., 2008, *Processing F_0 with Cochlear Implants: Modulation Frequency Discrimination and Speech Intonation Recognition*, "Hear Research", 235(1–2), 143–56.

Chin, S.B., Bergeson, T.R., Phan, J., 2012, *Speech Intelligibility and Prosody Production in Children with Cochlear Implants*, "Journal of Communication Disorders", 45(5), 355–366.

Fuller, C., Gaudrain, E., Clarke, J., Galvin, J.J., Fu, Q.J., Free, R., Başkent, D., 2014, *Gender Categorization is Abnormal in Cochlear-Implant Users*, "Journal of the Association for Research in Otolaryngology", 15, 1037–1048.

Gaudrain, E., Başkent, D., 2015, Factors *Limiting Vocal-Tract Length Discrimination in Cochlear Implant Simulations*, "Journal of the Acoustic Society of America", 137, 1298–1308.

Geers, A.E., Davidson, L.S., Uchanski, R.M., Nicholas, J.G., 2013, *Interdependence of Linguistic and Indexical Speech Perception Skills in School-Age Children with Early Cochlear Implantation*, "Ear and Hearing", 34, 562–574.

Gfeller, K., 2016, *Music-Based Training for Pediatric CI Recipients: A Systematic Analysis of Published Studies*, "European Annals of Otorhinolaryngology, Head and Neck Diseases", 133 (Suppl. 1), 50–56.

Gfeller, K., Driscoll, V., Kenworthy, M., Van Voorst, T., 2011, *Music Therapy for Preschool Cochlear Implant Recipient,* "Music Therapy Perspectives", 29(1), 39–49.

Green, T., Faulkner, A., Rosen, S., 2004, *Enhancing Temporal Cues to Voice Pitch in Continuous Interleaved Sampling Cochlear Implant*, "Journal of the Acoustical Society in America",116, 2298–2310.

Hopyan-Misakyan, T.M., Gordon, K.A., Dennis, M., Papsin, B.C., 2009, *Recognition of Affective Speech Prosody and Facial Affect in Deaf Children with Unilateral Right Cochlear Implants*, "Child Neuropsychology", 15, 136–146.

Hsiao, F., 2008, *Mandarin Melody Recognition by Pediatric Cochlear Implant Patients*, "Journal of Music Therapy", 45, 390–404.

Innes-Brown, H., Marozeau, J.P., Storey, C.M., Blamey, P.J., 2013, *Tone, Rhythm, and Timbre Perception in School-Age Children Using Cochlear Implants And Hearing Aids*, "Journal of the American Academy of Audiology", 24(9), 789–806.

Kalathottukaren, R.T., Purdy, S.C., Ballard, E., 2017, *Prosody Perception and Production in Children with Hearing Loss and Age- and Gender-Matched Controls*, "Journal of the American Academy of Audiology", 28(4), 283–294.

Lenden, J.M., Flipsen, P., 2007, *Prosody and Voice Characteristics of Children with Cochlear Implants*, "Journal of Communication Disorders", 40, 66–81.

Luo, X., Fu, Q.J., Galvin, J.J., 2007, *Vocal Emotion Recognition by Normal-Hearing Listeners and Cochlear Implant Users*, "Trends in Amplification", 11, 301–315.

Magne, C., Schön, D., Besson, M., 2006, *Musician Children Detect Pitch Violations in Both Music and Language Better Than Nonmusican Children: Behavioral And Electrophysiological Approaches*, "Journal of Cognitive Neuroscience",18, 199–211.

Meister, H., Landwehr, M., Pyschny, V., Walger, M., Wedel, H.V., 2009, *The Perception of Prosody and Speaker Gender in Normal-Hearing Listeners and Cochlear Implant Recipients*, "International Journal of Audiology", 48, 38–48.

Most, T., 2000, *Production and Perception of Syllable Stress by Children with Normal Hearing and Children with Hearing Impairment*, "Volta Review", 1012, 51–70.

Most, T., Peled, M., 2007, *Perception of Suprasegmental Features of Speech by Children with Cochlear Implants and Children with Hearing Aid*, "The Journal of Deaf Studies and Deaf Education", 12(3), 350–361.

Nakata, T., Trehub, S.E., Kanda, Y., 2012, *Effect of Cochlear Implants on Children's Perception and Production of Speech Prosody*, "Journal of the Acoustical Society of America", 131, 1307–1314.

Olszewski, C., Gfeller, K., Froman, R., Stordahl, J., Tomblin, B., 2005, *Familiar Melody Recognition by Children and Adults Using Cochlear Implants and Normal Hearing Children*, "Cochlear Implant International", 6, 123–140.

Palmer, C., Jungers, M.K., Jusczyk, P.W., 2001, *Episodic Memory for Musical Prosody*, "Journal of Memory and Language", 45, 526–545.

Patel, A.D., 2006, *Musical Rhythm, Linguistic Rhythm, and Human Evolution*, "Music Perception", 24, 99–104.

Peng, S.C., Tomblin, J.B., Turner, C.W., 2008, *Production and Perception of Speech Intonation in Pediatric Cochlear Implant Recipients and Individuals with Normal Hearing*, "Ear Hearing", 29(3), 336–351.

Saffran, J.R., Johnson, E.K., Aslin, R.N., Newport, E.L., 1999, *Statistical Learning of Tone Sequences by Human Infants and Adults*, "Cognition", 70, 27–52.

Schön, D., Magne, C., Besson, M., 2004, *The Music of Speech: Music Training Facilitates Pitch Processing in Both Music And Language*, "Psychophysiology", 41(3), 341–349.

See, R.L., Driscoll, V.D., Gfeller, K., Kliethermes, S., Oleson, J., 2013, *Speech Intonation and Melodic Contour Recognition in Children with Cochlear Implants and with Normal Hearing*, "Otology & Neurotology", 34(3), 490–498.

Snow, D., Ertmer, D., 2009, *The Development of Intonation in Young Children with Cochlear Implants: A Preliminary Study of the Influence of Age at Implantation and Length of Implant Experience*, "Clinical Linguistics & Phonetics", 23, 665–679.

Torppa, R., Faulkner, A., Huotilainen, M., Järvikivi, J., Lipsanen, J., Laasonen, M., Laasonen, M., Vainio, M., 2014, *The Perception of Prosody and Associated Auditory Cues in Early-Implanted Children: The Role of Auditory Working Memory and Musical Activities*, "International Journal of Audiology", 53(3), pp. 182–191.

Trehub, S.E., Vongpaisal, T., Nakata, T., 2009, *Music in the Lives of Deaf Children with Cochlear Implants*, "Annals of the New York Academy of Sciences",1169, 534–542.

Van Zyl, M., Hanekom, J.J., 2013, *Perception of Vowels and Prosody by Cochlear Implant Recipients in Noise*, "Journal of Communication Disorders", 46, 449–464.

Volkova, A., Trehub, S.E., Schellenberg, E.G., Papsin, B.C., Gordon, K.A., 2013, *Children with Bilateral Cochlear Implants Identify Emotion in Speech and Music*, "Cochlear Implants International", 14(2), 80–91.

Vongpaisal T., Trehub S.E., Schellenberg E.G., 2006, *Song Recognition by Children and Adolescents with Cochlear Implants*, "Journal of Speech Language and Hearing Research", 49, 1091–1103.

Waltzman, S., Hochberg, I., 1990, *Perception of Speech Pattern Contrasts Using a Multichannel Cochlear Implant*, "Ear & Hearing", 111, 50–55.

Wang, W., Zhou, N., Xu, L., 2011, *Musical Pitch and Lexical Tone Perception with Cochlear Implants*, "International Journal of Audiology", 50, 270–278.

Wysocka, M., 2012, *Prozodia mowy w percepcji dzieci*, Lublin.

Wysocka, M., Mackiewicz, L. 2017, *Odbiór emocji wyrażonych w prozodii przez dzieci z uszkodzonym narządem słuchu*, „Logopedia Silesiana", 6, in print.

Wysocka, M., Mackiewicz, L., 2016, *Percepcja intonacji u dzieci z uszkodzonym narządem słuchu*, „Logopedia", 45, 73–89.

Xu, L., Zhou, N., Chen, X., Li Y., Schultz H.M., Zhao X., Han D., 2009, *Vocal Singing by Prelingually-Deafened Children with Cochlear Implants*, "Hearing Research", 255(1–2), 129–134.

Yucel, E., Sennaroglu, G., Belgin, E., 2009, *The Family Oriented Musical Training for Children With Cochlear Implants: Speech and Musical Perception Results of Two-Year Follow-Up*, "International Journal of Pediatric Otorhinolaryngology",73(7), 1043–1052.