DEAFNESS

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Intonation perception in hearing-impaired children

SUMMARY

The speech of hearing-impaired persons, especially those with prelingual impairment, exhibits observable disorders of perception and realization of prosodic features and phenomena. The disorders particularly affect the perception of basic frequency of speech signals, changes of which (frequency) form intonation structures, contribute as the main factors to forming phrasal stress, and play a significant role in coding the emotional marking of prosodic structures. The primary causes of the foregoing irregularities are the impaired auditory control of utterances of the surrounding people resulting in the inability to fully use the proper patterns of prosodic structures, and impaired auditory self-control.

The article presents the results of the author's studies on intonation perception by six-to-eleven-year-old children with prelingual hearing impairment, with moderate, severe and profound hearing loss, as well as children with perilingual hearing impairment, with mild, moderate, and severe hearing loss. The obtained results confirmed the influence of early-onset prelingual hearing loss on the occurrence of severe disorders in the development of perception of intonation structures.

Keywords: perception of speech prosody, hearing impairment, prosody disorders

INTRODUCTION

In patients with hearing impairments, especially with severe and profound ones, speech prosody is subject to a wide range of disorders. The most frequently listed features of disordered prosodic realizations are: the heightened mean basic frequency that builds intonation contours, its instability, and high variability or a narrow range of changes. Disorders also affect articulation duration and the use of pausing. They also manifest themselves during chanting. Observable in the speech of hearing-impaired persons is also the instability of intensity of speech sounds (after: Trochymiuk 2008; Lorenc 2015).

The cause of these abnormalities is the impaired auditory perception of utterances of the surrounding persons, which results in the inability to fully use the correct patterns of prosodic structures, and impaired auditory self-control leads to the rise of adverse changes within the speech apparatus. The disordered realization of prosodic structures by patients with impaired hearing is largely determined by disorders of the voice-producing function (Maniecka-Aleksandrowicz and Szkiełkowska 1998; Szkiełkowska 2015).

It should be emphasized that among the studies devoted to the disorders of speech prosody in hearing-impaired persons the prevalent ones are the studies on the realization of prosodic structures. Research studies on their perception are far less numerous.

The goal of my own research presented in this paper is to verify the hypothesis on the impact of the prelingual and perilingual impairment of the speech organ on intonation perception in children aged 6–11 years. Intonation is understood here as a prosodic phenomenon resulting from temporal changes in the basic frequency of speech signal. This research was undertaken because of the insufficient number of published data on intonation perception by Polish-speaking hearing-impaired children. The authors undertook their research on intonation because it is a very important prosodic phenomenon that fulfills many functions in communication, the most frequent being to indicate the receiver through intonation contours of particular sentence types and the relationship between intonation and phrasal stress which organizes the thematic structure of utterances. Intonation structures also participate in communicating emotions (cf. inter alia Jassem 1973; Wierzchowska 1980; Demenko 1999; Botinis, Granström and Möbius 2001).

1. **Expression of intonation**

As deficits in the expression of prosodic features and phenomena in hearing-impaired patients are very distinctive, many research papers have been devoted to the problem. The largest number of research studies on the realization of prosody by hearing impaired persons is concerned with intonation.

Scholars point out the higher mean basic frequency in the speech of hearing-impaired patients and its low stability (Demenko et al. 1989). E. Stathopoulous et al. (1986) show that the mean basic frequency of intonation structures in hearing-impaired subjects is higher than in the speech of hearing persons; this particularly applies to the female population (269 Hz compared with 232 Hz in the speech of hearing women). The studied women with hearing loss used a higher mean basic frequency recorded at the beginning of phrases as compared with hearing women (279 Hz, with 254 Hz recorded in hearing women), and at their end (268 Hz compared with 189 Hz).

Research into the relationship between disorders in individual voice parameters and the kind of hearing loss plus the time of commencing rehabilitation has demonstrated that out of all the voice parameters, only basic frequency shows a strong correlation with the foregoing factors. The more severe the hearing loss and the later the time of prosthesis placement and commencement of treatment, the higher is the mean basic frequency in speech (Coelhoa et al. 2016). The severity of impairments in basic frequency is also related to the moment when the hearing organ was impaired, and it is the highest in patients in whom impairment occurred in the prelingual period (Pruszewicz et al. 1993). The high value of basic frequency suggests weak phonatory control, often connected with the higher position of the larynx, intense phonatory effort, and increased subglottal pressure.

The speech prosody in persons with hearing loss also differs from that in hearing people by the range of intonation contours. Stathopoulous et al. (1986) reported a smaller range of basic frequency in the studied female hearing-impaired subjects (157 Hz with the range of 192 Hz in the female control group). The phenomenon of intonation monotony caused by the narrow range of changes in basic frequency is also indicated by other researchers (Hood and Dixon 1969; Karczewska et al., 2000; Sieńkowska et al. 2000; Gubrynowicz and Sieńkowska 2001). The conclusion about the narrower range of basic frequency in intonation contours was also arrived at by G. D. Allen and P. M. Arndorfer (2000). This tendency, they believe, manifests itself particularly in the rising contours, which are less strongly marked in the speech of persons with hearing loss (49.9% of contours identified by hearing receivers as rising as compared with 96% identified in the speech of hearing persons). Other authors arrived at different conclusions (Stathopoulous et al. 1986; Sieńkowska et al. 2000; Gubrynowicz 2002), arguing that the problems of hearing-impaired patients in intonation expression mainly concern falling contours and are caused by the failure to signal the end of a declarative utterance by means of a distinct cadence.

The research results presented by several Polish scholars (Karczewska et al. 2000; Sieńkowska et al. 2000; Gubrynowicz and Sieńkowska 2001) show a positive effect of treatment using the polysensory auditory-vocal method on the voice and intonation skills in children with prelingual profound hearing loss. The intonation of children in the control group, not treated with the method described in the foregoing publications, was characterized by a narrow range of changes in the height of intonation contours while the characteristics of intonation in children undergoing the therapy in question did not significantly differ (apart from less intense voice modulation in the falling contours of declarative sentences) from the intonation of hearing children in the control group. Studies made after twenty years show that the ability to express intonation, developed during therapy in childhood, is also present in the adult subjects (Gubrynowicz and Sieńkowska 2001; Gubrynowicz 2002).

2. Intonation perception

Impairment of hearing results in the inability to fully utilize the patterns of prosodic structures present in the speech of the surrounding people. Hearing-impaired persons find it difficult to recognize some prosodic phenomena, in particular those that are connected with changes in the basic frequency of speech signal. Research results show that these persons perceive intonation structures, especially in noise, much worse than the hearing subjects (Luo et al. 2009; Meister et al. 2011), as well as differences between falling and rising intonation, and phrasal stress (Chatterjee and Peng 2008; Meister et al. 2009). They also identify emotions encoded in prosody with lesser accuracy (Luo, Fu and Galvin 2007; Hopyan-Misakyan et al. 2009) while they find it far easier to perceive phenomena based on duration (Moore and Glasberg 1988). The results of studies carried out by H. Van Zyl and D. Hanekom (2013) also show that implanted persons better perceive the structures based on the temporal distribution of elements compared to the structures based on the contour of basic frequency. The foregoing authors emphasize that in the tests for discrimination of intonation contours the implanted subjects obtain far worse results than the hearing persons (both in sentences in which the material is presented in silence and in noise). The evidence that hearing-impaired persons prevalently use time information rather than frequency information in perceiving prosodic structures is the fact that the perception of basic frequency in intonation contours always deteriorates when the receiver is deprived of the possibility to perceive temporal structures and the complete spectrum structure of a signal (Stickney et al. 2004).

Green and associates (2004; 2005) emphasize that the perception of intonation structures based on rhythm and stress structures is strongly determined by temporal context (duration of particular segments of a speech signal) and by their intensity. They argue that the fact of perception of intonation structures does not necessarily have to denote the ability to accurately detect changes in basic frequency. The continuation of this thinking can be found in the study by M. Chatterjee and Shu-Chen Peng (2008), who investigated the ability to detect changes in basic frequency by implanted adults (in the range of from 50 to 300 Hz), connected with the function of intonation contour (signaling a question or statement). In the tests, a two-syllable word was used, which was acoustically modified in order to obtain the diversity of frequency, duration and intensity of speech signal. The test also used natural utterances realized by women and men. Both the first and second test showed the leading role of the F_0 parameter in detecting intonation in structures with a lesser initial basic frequency (120 Hz). Significantly, greater difficulties occurred in the perception of intonation structures realized with the greater initial value of F_0 (from 200 Hz). In this type of tests the listeners had a tendency to focus on temporal structures.

3. Materials and methods

The aim of my study is to assess the impact of the prelingual and perilingual hearing impairment on intonation perception by children aged 6 to 11 years. To carry out the tests, the author's own diagnostic tool was used (Wysocka 2012), from which tests were selected, which enabled assessment of the ability to perceive intonation contours The test material used the intonation structures of the two-syllable word (*tata*) [daddy] and the seven-syllable sentence (*teraz idziesz do domu* [now you're going home]). In order to check the impact of the effect of desemanticization of intonation structures (by severing the relationship between intonation contours and lexical meaning) on their perception, this study also used structures based exclusively on the vowel realizations of the foregoing word and sentence characterized by very similar acoustic parameters in terms of full-text structures.

Test tasks were divided into tasks for discriminating intonation structures (full-text and vowel ones) given in pairs, and the tasks for defining the direction of their contour. The tests used 10 tasks each to discriminate the intonation of the two-syllable word, the seven-syllable utterance, and their vowel realizations, as well as five tasks each to define the direction of intonation contour in the word, sentence, and their vowel realizations.

The test material was recorded earlier. The frequency of basic vowels used in the material ranges as a rule between 170 to 500 Hz (mean value of F_0 being 270.19 Hz). The duration of realization of each structure did not exceed 3 seconds. In order to limit the influence of temporal organization on the perception of basic frequency, the rhythmic structure of the words used in the tasks and their vowel forms as well as the structure of sentences and their vowel forms is the same.[1]

The studied group consisted of ten children with bilateral hearing impairment during the prelingual period, and four children with bilateral impairment during the perilingual period. This selection of the subjects was meant to enable comparison between the results obtained by the children with earlier hearing impairment and with a greater degree of hearing loss, and the results of the children with a lower degree of hearing loss arisen at a later period. The characteristics of the subjects are shown in Table 1.

The tests were carried out individually with each child, in the room enabling the comfort of testing. Each test was preceded by explanations of procedures. A series of tasks was always preceded by two trial tasks accompanied by the explanation of how to execute them. After presenting instruction and explaining it, the test material was played and, if necessary, repeated at the request of the tested child or when the subject's failure to focus attention during presentation was ob-

[1] Detailed characteristics are contained in the paper *Prozodia mowy w percepcji dzieci* [Speech prosody in children's perception] (Wysocka 2012).

served. The subjects sat a distance of 1 to 1.5 meter from the audio speakers, in the position allowing the signal to simultaneously reach both ears. A sufficient sound level of the played material was provided and accidental sounds that might disturb the testing were eliminated.

In order to define the degree of development of intonation perception in the tested children with prelingual and perilingual hearing impairment, the percentage results they obtained were compared with the results of ten-subject groups of six- and seven-year-old hearing children and hearing adults tested with the same tool and according to the same procedure (results for the hearing persons – Wysocka 2012). The results of adults were given because of the lack of test results with the tool used in this study for children older than seven years.

4. Results

In accordance with the adopted assumptions, the results were discussed by two test groups: a) children with prelingual hearing impairment, b) children with perilingual hearing impairment. The study presented individual results for children in the tested groups and the overall results of the two groups compared with the results obtained by hearing subjects: six- and seven-year-old children as well as the group of adults.

4.1. Prelingual hearing-impaired children

The first skill to be assessed was discrimination of intonation structures in a word, sentence and their vowel realizations. Figure1 illustrates individual results obtained by children in intonation structure discrimination tasks.

Two subjects obtained very good results in intonation discrimination tasks (D5F and D7M, the average being 95 and 90% of correct answers respectively): children with severe sensorineural hearing loss. The children with codes D9F and D10M, with profound hearing loss, did not exhibit the tested ability (result: 0%). The remaining children scored results within 66.3 to 68.8 percent (D3F, D4M, D6M) or 33.4 to 37.7% (D1M, D2M, D8M). The average score obtained by the whole group in these tasks is 49.43% of correct answers. Six-year-old hearing children obtained 84.2% of correct answers (see Fig. 5), the difference therefore being 34.77 of percentage points.

In the other type of tasks consisting in determining the direction of intonation changes (defining its contour as rising or falling) the tested children achieved lower results than in the previous tasks: 38.5% on average in the whole group. However, the results obtained by hearing six-year-olds is 53.6% (see Fig. 5), the difference between the groups being only 15.1 of percentage points. The children's individual results are shown in Fig. 2

Table 1. Characteristics of the tested children with pre- and perilingual hearing impairment

Code and sex	Age	Time of beginning of impairment	Type of impairment	Degree of hearing loss	Kind of hearing prosthesis	Time of prosthesis placement	Way of communication	Beginning of speech	Logopedic therapy
D1 M	6.7	prelingual impairment (congenital)	sensorineural hearing loss	moderate hearing loss	hearing aids	3 year of age	phonic language + sporadically sign language	first words – 2 yr of age. sentences – 6 yr of age.	yes
D2 M	7.7	prelingual impairment (congenital)	sensorineural hearing loss	moderate hearing loss	hearing aids	3 year of age	phonic language	first words – 3 yr of age. sentences – 4 yr of age.	yes
D3 F	8.9	prelingual impairment (1 year of age)	mixed hearing loss	moderate hearing loss	hearing aids	2 year of age	phonic language	first words – 2 yr of age. sentences – 5 yr of age.	yes
D4 M	11.6	prelingual impairment (congenital)	sensorineural hearing loss	moderate hearing loss	hearing aids	7 year of age	phonic language	first words – 4 yr of age. sentences – 10 yr of age.	yes
D5 F	7.2	prelingual impairment (congenital)	sensorineural hearing loss	severe hearing loss	hearing aids	3 year of age	phonic language + sporadically sign language	first words – 1 yr of age. sentences – 3 yr of age.	yes
D6 M	11.0	prelingual impairment (congenital)	mixed hearing loss	severe hearing loss	hearing aids + FM system	1 year of age	phonic and sign language	first words – 2 yr of age. sentences – 3 yr of age.	yes
D7 M	11.3	prelingual impairment (congenital)	sensorineural hearing loss	severe hearing loss	hearing aid and implant	hearing aids from 6 months of age	phonic and sign language	first words – 1 yr of age. sentences – 7 yr of age.	yes

Code and sex	Age	Time of beginning of impairment	Type of impairment	Degree of hearing loss	Kind of hearing prosthesis	Time of prosthesis placement	Way of communication	Beginning of speech	Logopedic therapy
D8 M	9.7	prelingual impairment (congenital)	mixed hearing loss	profound hearing loss	hearing aids	3 year of age	phonic language + attempts to speak	first words – 4 yr of age. sentences – 7 yr of age.	yes
D9 F	9.2	prelingual impairment (1 year of age)	mixed hearing loss	profound hearing loss	initially hearing aids, currently implants	3 year of age – hearing aids. 4 year of age implant	phonic and sign language	first words – 4 yr of age. sentences – 7 yr of age.	yes
D10 M	11.4	prelingual impairment (1 year of age)	sensorineural hearing loss	profound hearing loss	cochlear implant - left ear	5 year of age	phonic language	single words since recently	no
D11 M	10.9	perilingual impairment	conductive hearing loss	mild hearing loss	no hearing prosthesis	none	phonic language	first words – 4 yr of age. sentences – 8 yr of age.	yes
D12 M	11.8	perilingual impairment	conductive hearing loss	mild hearing loss	no hearing prosthesis	none	phonic and sign language	first words – 6 yr of age. So far – single words and short utterances	yes
D13 M	10.1	perilingual impairment 1	conductive hearing loss	moderate hearing loss	hearing aids	8 year of age	phonic and sign language	first words – 3 yr of age. sentences – 7 yr of age	no
D14 F	9.7	perilingual impairment	conductive hearing loss	severe hearing loss	hearing aids	7 year of age	phonic language	first words – 2 yr of age. sentences – 6 yr of age.	yes

Source: Authors' own elaboration

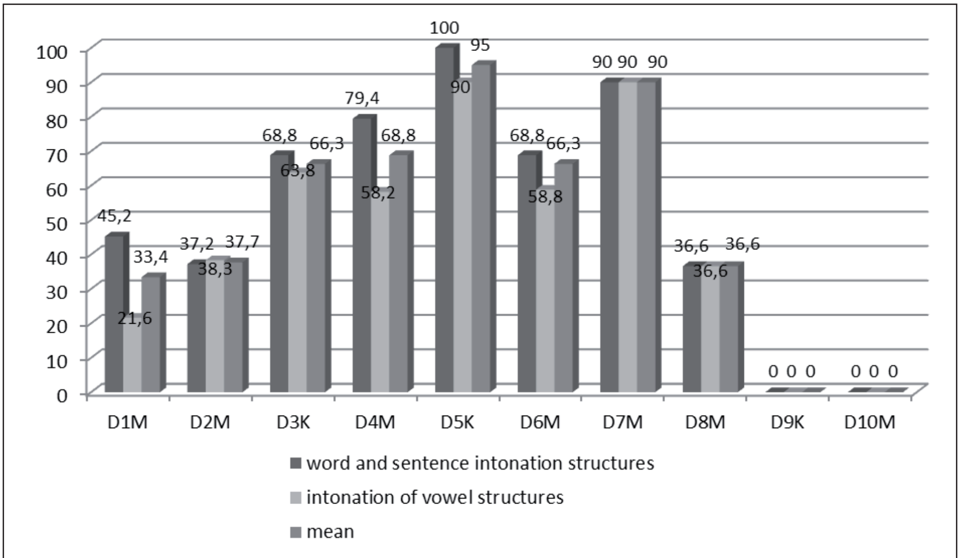

Figure 1. Percent results obtained by prelingual hearing-impaired children in intonation structure discrimination tasks (%)
Source: Authors' own elaboration

The highest score was again achieved by the girl coded as D5F (with the average of 75%) and the girl coded as D3F (70%). In the tasks for defining the direction of intonation contours, most of the children obtained lower results (two ranging from 50 to 55% and four from 20 to 40%) or did not at all exhibit the tested ability (two children). Worth noting are the results of the boy coded as D10M, who used the sign language only and did not undergo surdologopedic therapy. As the only one in the whole group he did not exhibit any of the diagnosed abilities (in all tasks, both discrimination and determination tests, he scored zero results).

Table 2 presents detailed scores obtained by individual subjects.

When analyzing the obtained results we can conclude that there is a slight decreasing tendency in the correct results as the length of elements increases, which is found in both task types: discrimination and determination. This tendency applies to both intonations realized in words and sentences with a complete segmental structure, and to their vowel realizations. This prompts the conclusion that the subjects found it more difficult to analyze the longer, multi-element structures largely involving short-term auditory memory.

Desemanticization of the language material used in the testing, made through elimination of consonants from the structure of the word and sentence, influenced the decrease in the correct answers in tasks determining the direction of word and sentence intonation contour and in tasks for sentence intonation discrimination

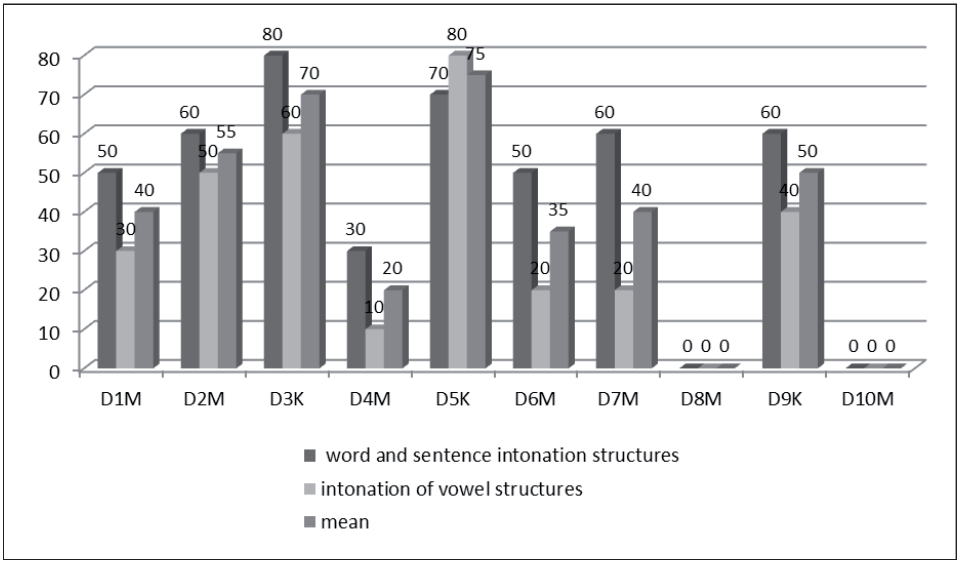

Figure 2. Percent results obtained by prelingual hearing-impaired children in tasks determining intonation structures (%)

Source: Authors' own elaboration

whereas in tasks for word intonation discrimination and their vowel realizations the effect of desemanticization did not result in worse scores. It could be therefore concluded that the possibility of utilizing the complete structure and semantics of linguistic units was particularly important to the tested children in more difficult tasks that required the use of auditory memory to a large extent, while depriving them of this possibility resulted in decreased scores.

4.2. Perilingual hearing-impaired children

In intonation structure discrimination tasks the group of perilingual hearing-impaired children obtained the mean score of 65.67% of correct answers. The results of are shown in Fig. 3.

The highest accuracy characterizes the answers of the nine-year-old girl, the youngest in the group, with the highest (severe) degree of hearing loss. The high results she achieved (average: 82.5%) can be attributed to the fact that her hearing impairment developed comparatively late and she received a hearing aid the earliest among the children in the group: at the age of seven (other children – later or not all). The girl is also provided with surdologopedic therapy. Owing to these factors, despite her severe hearing loss, she is distinguished by a high general level of linguistic functioning, which is evidenced by the observation and history data.

For the tasks determining the direction of intonation changes the group obtained the average score of 47.5% of correct answers. As was the case with the

Table 2. Detailed percent results obtained by prelingual hearing-impaired children in tasks for intonation structure discrimination and determination (%). NU – moderate hearing loss, NZ – severe hearing loss. NG – profound hearing loss.

Code, sex, and degree of hearing loss	All tasks average	Word intonation		Intonation of vowel realization of word		Utterance intonation		Intonation of vowel realization of utterance	
		discrimination	direction determination	discrimination	direction determination	discrimination	direction determination	discrimination	direction determination
D1M (NU)	37.35	55.5	60	33.3	40	40	40	10	20
D2M (NU)	46.37	44.4	100	66.6	40	30	20	10	60
D3F (NU)	68.17	77.7	100	77.7	80	60	60	50	40
D4M (NU)	44.42	88.8	40	66.6	20	70	20	50	0
D5F (NZ)	85	100	80	100	80	100	60	80	80
D6M (NZ)	49.42	77.7	80	77.7	20	60	20	40	20
D7M (NZ)	55.12	100	80	100	20	80	40	80	20
D8M (NG)	18.32	33.3	0	33.3	0	40	0	40	0
D9F (NG)	25	0	60	0	40	0	60	0	40
D10M (NG)	0	0	0	0	0	0	0	0	0

Source: Authors' own elaboration

prelingual hearing-impaired children, the results in the other group were lower as compared with discrimination tasks. The scores of individual children are shown in Fig. 4.

In this studied group the highest scores were obtained by a ten-year-old boy (D12M) with mild hearing loss and again by the girl coded as D14K. The only child in the group who did not undergo speech-therapy treatment is a boy coded as D13M. He also scored the lowest result (on average, 45.17% of correct answers) in both task types: discrimination and determination.

The detailed comparison of results obtained by individual children (Table 3) shows, similarly to the results of prelingual hearing-impaired children, a decrease in correct answers as the intonation structure in the word and sentence and their vowel realizations lengthen.

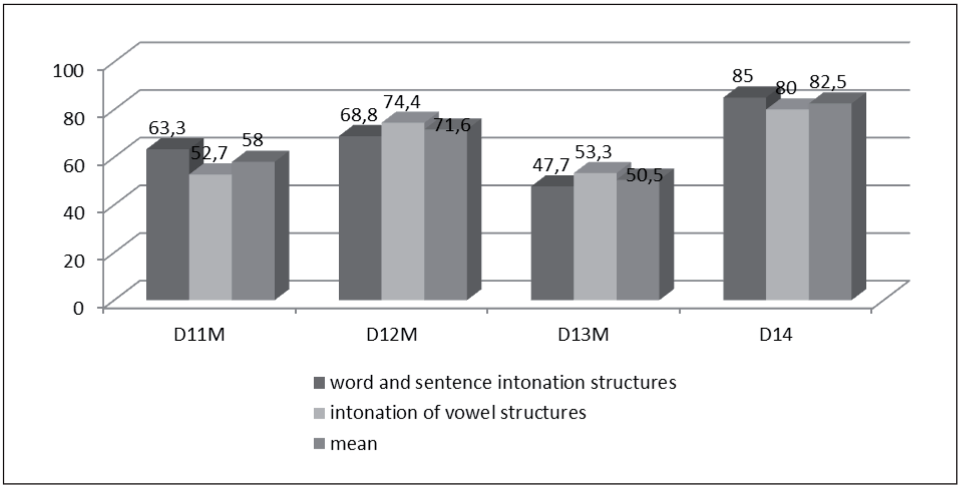

Figure 3. Percent results obtained by perilingual hearing-impaired children in intonation structure discrimination tasks (%)

Source: Authors' own elaboration

The elimination of consonants from the test material did not result in the decrease in correct answers only in word discrimination tasks. In the other tasks, the children scored far lower results in the perception of vowel structures as compared with full-text structures. This leads to the conclusion that also in this group of subjects the absence of the possibility to use the full structure of words and, consequently, their semantics, caused a decrease in correct answers in more difficult tasks.

CONCLUSIONS

The obtained testing results confirmed the influence of the time when the hearing impairment occurred on the tested children's ability to perceive intonation structures. The chart below (Fig. 5) compares the results obtained by the tested hearing-impaired children with the results of hearing six- and seven-year-old children and adults.

The foregoing chart shows that the lowest scores were obtained by with prelingual hearing impaired children. Worth noting is the fact that perilingual hearing-impaired children and with a much lesser degree of hearing loss scored much lower results than hearing children in the youngest age groups, which leads to the conclusion that even the later hearing impairment and lesser degree of hearing loss significantly reduce the development of the ability to perceive intonation structures. It should be also emphasized that children with hearing loss, like

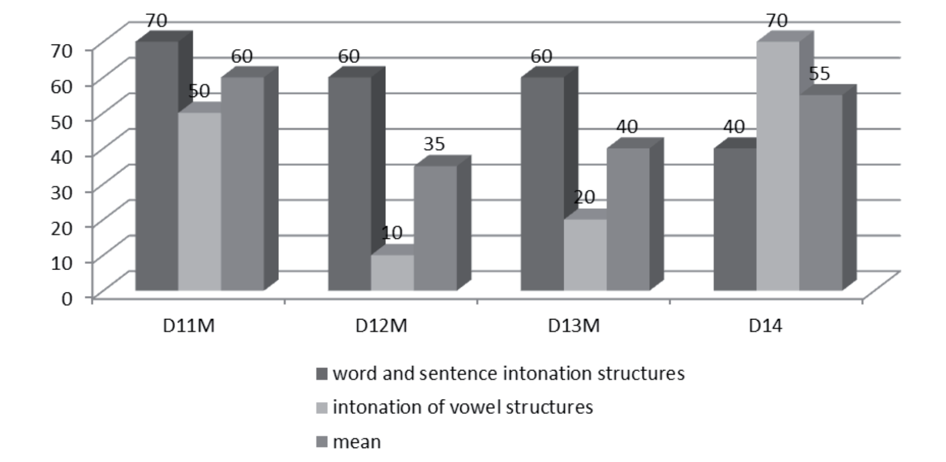

Figure 4. Percent results obtained by perilingual hearing-impaired children in intonation structure determination tasks (%)

Source: Authors' own elaboration

Table 3. Detailed percent results obtained by perilingual hearing-impaired children in tasks for intonation structure discrimination and determination (%). NL – mild hearing loss, NU – moderate hearing loss, NZ – severe hearing loss.

Code, sex, and degree of hearing loss	All tasks average	Word intonation		Intonation of vowel realization of word		Utterance intonation		Intonation of vowel realization of utterance	
		discrimination	direction determination	discrimination	direction determination	discrimination	direction determination	discrimination	direction determination
D11M (NL)	59.01	66.6	80	55.5	60	60	60	50	40
D12M (NL)	53.31	77.7	80	88.8	20	60	40	60	0
D13M (NU)	45.26	55.5	80	66.6	20	40	40	40	20
D14F (NZ)	68.75	100	40	100	80	70	40	60	60

Source: Authors' own elaboration

hearing persons, have a greater problem determining the direction of intonation changes. The scores for discrimination tasks are higher. The difficulty of direction determination tasks is caused by the fact that the tested subject is expected not only to have an efficient perception of intonation structures but also possess knowledge on their structure and the ability to use it intentionally.

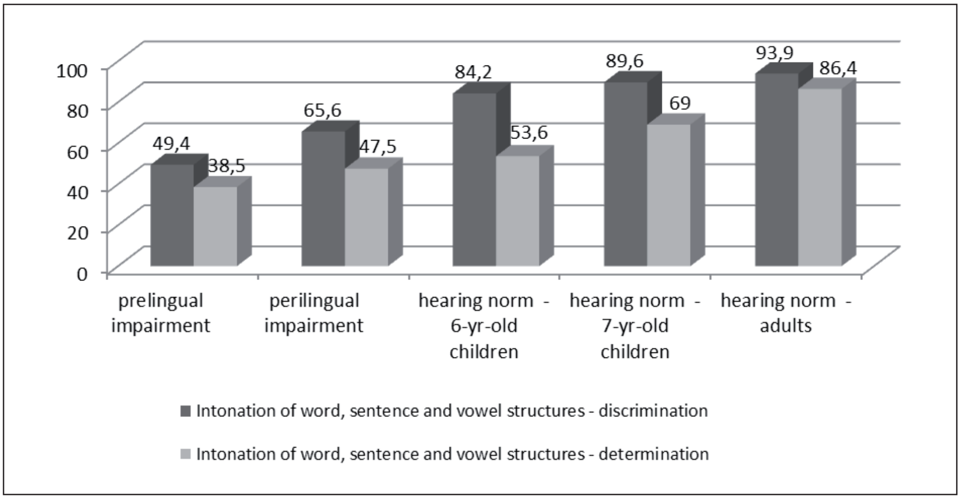

Figure 5. Comparison of results obtained by tested children with hearing loss with results of hearing children and adults (%)

Source: Authors' own elaboration. Data for hearing-normal subjects: Wysocka 2012.

The factor that influences the skill in perceiving intonation structures by the tested children may also be surdologopedic therapy. The children who did not receive it (Coded as D10M and D13M) obtained the lowest results in the studied groups.

The results of studies (tests) presented in the article correspond with the data from the cited foreign literature that confirm the difficulties of children and adults with hearing loss in perceiving intonation structures based on temporal changes in basic frequency. Disorders in this area affect not only the inability to acquire their auditory patterns and use diverse intonation structures in speech but are also due to the fact many linguistic and paralinguistic functions performed by intonation and influencing speech development in ontogeny are not fully accessible to children with hearing loss. The functions mainly include: segmentation of the phonic sequence, especially into phrases; communication of information about the type of utterance (characteristic intonation contours suggest declarative and imperative utterances, or yes/no questions); semantic function connected with determining the position of phrasal stress by the intonation structure; and the contribution of intonation structures to encoding information associated with the emotions and intentions of the sender of a linguistic message.

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