Binaural Masking Levels Difference in children with Language-based Learning Disability correspond to speech in noise comprehensiveness

Binaural Masking Levels Difference u dzieci z zaburzeniami uczenia się na drodze językowej koreluje z rozumieniem mowy w szumie

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Introduction. In recent years, audiology and phoniatrics centres treat ever more school children with Language-based Learning Disability (LLD) which can be related to central auditory processing disorders. Binaural Masking Level Difference (BMLD) test is one of the central auditory tests which is independent of language and speech maturity.

Aim. The aim of the study was to assess BMLD in groups of school children with LLD, depending on their speech audiometry results in silence and in noise.

Materials and methods. Fourty five children with LLD were included to the study and divided into 3 groups. Group 1: 13 children with significantly poorer speech audiometry in noise as compared to speech audiometry in silence. Group 2: 17 children with poor results of speech audiometry in silence (speech discrimination ≤70%). Group 3: children with the same normal location of articulation curves in silence and in noise. The results of children with LLD were compared to the control group of 12 children with full educational potential and good hearing.

Results. The children with LLD with impaired speech understanding in the presence of competitive signal (group 1) had the poorest results of BMLD. In children with LLD and normal speech understanding in noise (group 3), as well as in control children without LLD, BMLD did not show abnormalities.

Conclusions. Impaired speech understanding in noise of a child with LLD corresponds well with poor values of BMLD.

Keywords: *Language-based learning disability LLD, Binaural Masking Level Difference BMLD, (Central) Auditory Processing Disorders (C)APDs, Speech audiometry*

Wprowadzenie. W ostatnich latach do ośrodków audiologiczno-foniatrycznych trafia coraz więcej dzieci z zaburzeniami uczenia się wynikajacymi z zaburzeń rozwoju języka (Language-based learning disability – LLD), które mogą zależeć od zaburzeń procesów ośrodkowego przetwarzania słuchowego. Binaural Masking Level Difference (BMLD) jest jednym ze słuchowych testów centralnych, którego wynik nie jest zależny od dojrzałości języka i mowy.

Cel pracy. Celem pracy była ocena BMLD w grupach dzieci w wieku szkolnym z LLD w zależności od wyników audiometrii mowy w ciszy i w szumie.

Materiał i metody. Bdaniami objęto 45 z LLD, które podzielono na trzy grupy. Grupa 1 – 13 dzieci z istotnie gorszymi wynikami rozumienia mowy w szumie w porównaniu z rozumieniem w ciszy. Grupa 2 – 17 dzieci z nieprawidłowym wynikiem rozumienia mowy w ciszy (stopień rozróżniania poniżej 70%). Grupa 3 – Dzieci z krzywymi artykulacyjnymi w ciszy i szumie o tej samej, normalnej lokalizacji. Wyniki uzyskane u dzieci z LLD porównano z grupą kontrolną 12 dzieci bez trudności w nauce i z prawidłowym słuchem.

Wyniki. Dzieci z LLD i upośledzonym rozumieniem mowy w szumie (grupa 1) miały najgorsze wyniki testu BMLD. U dzieci z LLD i prawidłowym rozumieniem w szumie (grupa 3), jak również w grupie kontrolnej test BMLD nie wykazywał nieprawidłowości.

Wnioski. Upośledzenie rozumienia w szumie u dzieci z LLD jest skorelowane z istotnie gorszymi wartościami testu BMLD.

Słowa kluczowe: *nieprawidłowy rozwój języka, Binaural Masking Level Difference BMLD, zaburzenia procesów ośrodkowego przetwarzania słuchowego, audiometria mowy*

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Introduction

Over a hundred years ago, a far-reaching social experiment started – which has continued until the present day – connected with placing developing minds in a new environment, school. Before that, not many had had the privilege of taking part in systematic teaching. It turned out that not all children were able to meet the challenges associated with the growing expectations of adult members of modern society.

Intense education starting at an early age revealed that normal intelligence is not enough to stand up to the challenges of contemporary school [1].

Over the last few decades, pupils who failed to cope with school requirements were grouped together. New entities and syndromes emerged, such as: AD/HD (Attention Deficit /Hyperactivity Disorder), dyslexia, Specific Language Impairments, etc. Children with difficulties in school adaptation and learning have required assistance from representatives of various fields of science: psychologists, speech and language therapists, pedagogues, neurologists, psychiatrists, and – ever more often – audiology physicians.

As early as in 1954, Helmer Myklebburst indicated the necessity of examining central auditory processing disorders in children with disturbed communication. He stressed that researchers cannot limit themselves to plotting the audiograms for patients with, as he defined it, auditory imperception, or difficulties that cannot be explained by incorrect functioning of the peripheral section of the auditory tract [2].

In the 1950s, the diagnostics of central auditory processing began to develop, designed for patients with auditory cortex lesions following surgical procedures [3,4]. In 1961, Kimura discovered the asymmetry of auditory cortical centers and explained the rudiments of dichotic listening [5].

Only as late as in the 1970s did people begin to associate learning difficulties with irregularities in hearing functions of the upper auditory centers. It was then that a new concept was coined in medicine, that of (Central) Auditory Processing Disorder [6-8].

Until the present day, there has been no concise definition nor clear-cut criteria for that disorder. According to ASHA 2005, central auditory processing is defined as: the neuronal processing of auditory information in the central nervous system, as well as neurobiological activity, which is registered after auditory stimuli are applied [9].

In accordance with the British Society of Audiology, (C)APD is a disorder resulting from impaired neural function and it is characterized by poor recognition, discrimination, separation, grouping, localization, or ordering of sounds which are not constituents of speech [10].

Disturbances in auditory processing are the impairments of auditory signal processing in auditory tract neurons. This disorder cannot be caused by impaired higher mental functions: speech-related, cognitive, etc; whereas (C)APD leads to incorrect development of speech and higher cognitive functions, which handicaps and modifies intellectual development and learning progress [11].

It has been estimated that about half of the children with learning difficulties have problems with auditory processing, while in the entire schoolchildren population that disorder occurs in 2-5% of individuals [12].

A whole set of tests have been developed for the assessment of specific auditory processing functions. Unfortunately, a large majority of those tests contain constituents of speech, and performance of a task that does not depend merely on the efficiency of the auditory tract, but also upon the level of speech and language development [13,9].

Objective electrophysiologic tests failed to meet the expectations concerning the assessment of higher auditory activities. Irregularities in the records of auditory middle-latency responses and P300 wave occur only in about 40% of children with diagnosed (C)APDs. For the sake of comparison, in as many as nearly 30% of those patients irregularities are registered in reflexes from middle ear muscles [14].

A relatively sensitive and simple test to check the interactions within the auditory pathways is the Binaural Masking Level Difference (BMLD). The test is based on diotic listening, when the signal and masking noise, provided to both ears, remain in changing phase dependencies. Such listening is connected with the so-called "cocktail party" effect, where the signal and masking sounds have different source locations in space (another type of binaural hearing is dichotic listening, where those dependencies are time-related). Usually, a pulsating or constant tone is used in BMLD test; however, phones (spondees) of speech may be also used. The test consists of the presentation of a signal to both ears at the same time, during which a masking noise is also binaurally provided. The auditory threshold for the signal is checked in two ways, depending upon whether signal and noise are presented in the same phase (homophasic) or in the opposite phase (antiphasic) [15]. In homophasic conditions, the signal and noise are presented in the same phase to both ears (SoNo), whereas in antiphasic conditions one of the two signals is shifted by 180° out of phase, while the second sound remains in phase between the ears, e.g. SoNπ.

The difference in auditory thresholds for the signals obtained for the SoNπ – SoNo conditions is determined as BMLD. In people with correct functioning of brainstem centers, the auditory threshold in antiphasic conditions is lower. This hearing improvement after shifting one of the sounds by 180° between the ears is referred to as release from masking [16].

If broad-band noise is used, the BMLD values will be higher for low frequencies, and will amount to 15 dB on average, whereas for frequencies exceeding 2 kHz they achieve merely 2-3 dB [17,18]. If, however, narrow-band noise is used instead of a broad-band one, BMLD in a low frequency range may reach as much as 25 dB, while in higher frequencies those values may reach 15 dB [19,20].

The BMLD phenomenon is related to the ability of sound location, and is generated in midbrain inferior colliculus [21,22].

The aim of the study was to assess BMLD test results in school children with language-based learning disability (LLD), depending on their speech audiometry performance in silence and in noise.

MATERIALS AND METHODS

Materials

In the years 2003-2011, 196 patients at school age (8-15; mean 10.5) were referred to consultation by audiology physician for Language-based Learning Disability (LLD). Tentative diagnosis of LLD was made by a team of school speech and language specialists and psychology services.

From entire group, 45 patients (29 boys and 16 girls), were selected to this study and they were divided according to the speech audiometry test results into 3 groups.

Group 1 comprised 13 school children for whom the location of articulation curves in silence and in noise, for the same articulation test, differed significantly. As the location of curves was clearly different for each of those children in the upper section (after crossing SRT), we selected only those patients for whom the repetition of 60% or (and) 70% of words after the application of noise required an increase in sound volume of at least 20 dB as compared to the same test carried out in silence.

Group 2 comprised 17 school children for whom a distinct speech discrimination loss of 30% or more has been noted for the Polish monosylabic test NLA 93. It means that the articulation curve reached the plateau at the level of no more than 70% of word understanding (in some children that curve was bell shaped).

Group 3 comprised 15 school children with LLD for whom the location of articulation curves plotted in noise and in silence did not differ significantly. Both curves had normal shape and location.

The results of BMLD in children with LLD were referred to the control group (group 4) of 12 children at school age with full educational potential and good hearing.

All patients were examined by otorhinolaryngology specialist and underwent the set of psychological and audiological tests. The excluding criteria were as follows:

1. The intelligence quotient score below 85 in the Wechsler WISC-R test.
2. Hearing loss in pure tone audiometry.
3. No reliable results in BMLD tests.
4. Abnormal auditory brainstem response (ABR).

Methods

Speech audiometry examinations and the BMLD test were performed on clinical audiometer PC "Interacoustics Equinox", with TDH 39 headphones. In speech audiometry we used Polish monosyllabic words lists NLA 93 with noise in monootic condition, and with speech to noise (S/N) ratio – 5 dB.

In the BMLD examination, a pure tone of 500 Hz and a narrow-band noise (500 Hz center frequency, rise/fall 25 ms; 3 dB band with 100 Hz; 85 dB SPL) were used.

BMLD was measured by presenting interrupted tone together with narrow band noise at 60 dB to both ears in the phase (SoNo condition) and finding the threshold. Then, the phase of the signal or noise was inversed (SoNπ condition), an the threshold was established again. The patients were instructed to pay attention only to tone detection. The examination accuracy was 5 dB. Tests were repeated at least three times, until reliable (repeatable) results were obtained. The BMLD equals the difference between the in-phase and out-of- phase thresholds, or more formally the BMLD is defined as the difference in dB between binaural in phase condition (SoNo) and out of phase condition (e.g. SoNπ).

RESULTS

Result of ANOVA test revealed the absence of statistically significant differences due to age ($p>0.05$), what means that the average age was comparable in all four groups. Mean age of the study group ranged from 10.1 to 10.8 years and was 10.7 in the control group. The remaining 3 variables, namely: SoNo, SoNπ, and BMLD in those groups were compared using Kruskal-Wallis test, because of problems with normal distribution. No statistically significant differences occurred between the groups as regards SoNo (fig. 1). Significant differences were demonstrated to occur between the groups for SoNπ ($p=0.0060$), as well as for BMLD ($p=0.007$).

The highest values of SoNπ were observed in the group 1 (50 dB) as compared to other groups, although the statistical significance ($p<0.05$) was reached in comparison to the group 3 and the controls (fig. 2). BMLD test revealed the lowest values in the group 1, and their results were significantly different from the results received in the group 3 ($p<0.01$) only (fig. 3).

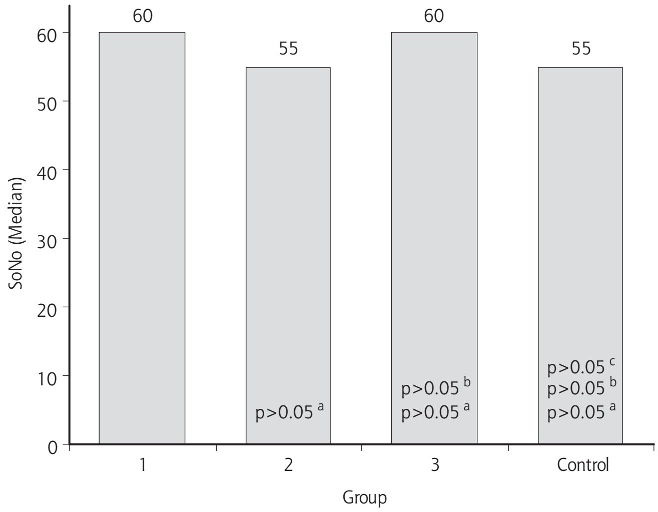

Fig. 1. Between-group differences of SoNo values (Kruskal-Wallis test; KW=1.066; $p>0.05$)

[a] against group 1, [b] against group 2, [c] against group 3

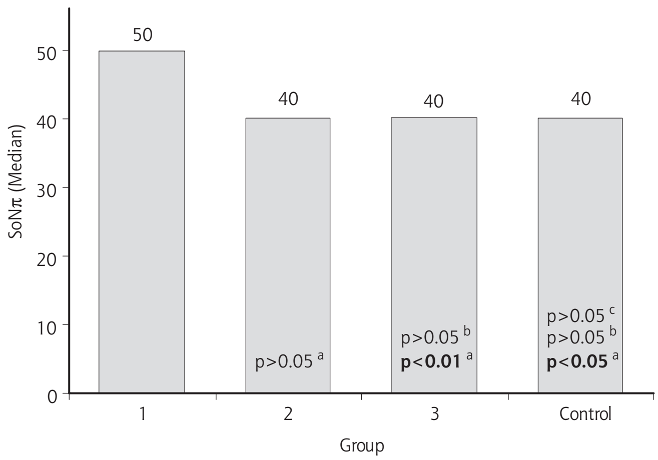

Fig. 2. Between-group differences of SoNπ values (Kruskal-Wallis test; KW=12.455; $p<0.01$)

[a] against group 1, [b] against group 2, [c] against group 3

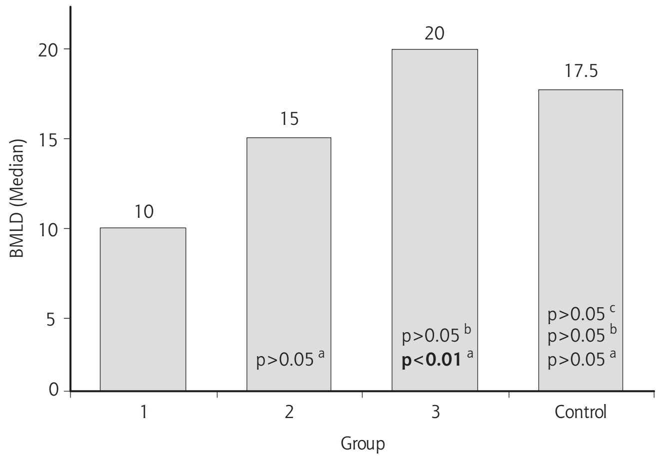

Fig. 3. Between-group differences of BMLD values (Kruskal-Wallis test; KW=12.12; $p<0.01$)

[a] against group 1, [b] against group 2, [c] against group 3

DISCUSSION

Diagnosis of LLD is based on psychological and speech therapist evaluation and may comprise several disabilities, including central auditory processing disorder. More specific audiological diagnosis is crucial before implementation of individual rehabilitation procedures.

BMLD test is rarely included in clinical central auditory test batteries, perhaps because it does not directly assess either localization or lateralization. It has been shown to be sensitive to lower level brainstem dysfunction. Embedding speech in background noise is one of strategies employed for reducing the natural redundancy in speech signals. This test is useful in both the diagnosis of (C)APD and in describing functional auditory abilities (e.g. auditory closure) [23]. In this study, the results of these two test were compared in group of children with diagnosed LLD.

In the tests used in the study in a diotic way, a tone of 500 Hz frequency, masked by noise was provided to both ears – SoNo, then reversed in one ear to SoNπ condition. Such a combination of signal and noise should result in a release from masking, thus it should improve tone detection.

BMLD, besides otoacoustic emissions suppression, is one of the few tests assessing the efficiency of the higher regions of the auditory tract, independent of the acquired language competencies [24]. That is why in our opinion it is particularly useful in diagnosing children with language-based learning difficulties. Experiments on animals demonstrated that the BMLD phenomenon is generated in neurons of midbrain tectum, in inferior colliculus. That is why it may be assumed that BMLD below the average may indicate an impaired function of this part of the auditory tract [21,22]. On the other hand, the deficit in binaural processing leads to deteriorated functioning in a noisy environment and impaired directional hearing that adversely affect school progress and the intellectual development of a child [25]. Another disease, for which the main manifestation is a reduced tolerance for background noise, is auditory neuropathy [26]. In all patients from group one we managed to perform an ABR examination; the response record was within the normal range. That is why auditory neuropathy was not recognized in any of those patients.

BMLD is not a time consuming test, nevertheless it requires a relatively well developed ability of focusing attention. In order to obtain a reliable, repeatable response, the test should be repeated at least three times.

It is very important to instruct the patient to focus upon tone detection and to ignore the noise. The „step up and down" method suggested by Moore, where relies on starting the examination with providing easily "extractable" tones; in steps of 10 dB to start with, and then of 5 and 2 dB, by increasing and decreasing their intensity. However, this procedure significantly prolongs the examination time and thus reduces its clinical value [25]. Van Deun et al. claim that the test may be applied in diagnosing 5-year old or younger children [27]. In the material from our centre, the results obtained in such young patients were hardly reliable, in particular in children with disturbed development of the communication process.

In two groups of children speech audiometry were performed two times, first in the condition of laboratory silence and then, on another day, using the same articulation list in noisy condition at a sound to noise ratio (S/N) of -5 dB. The examination should be carried out with intermissions of a few days, so as to preclude the child remembering the words from the list [28].

Significantly lower BMLD values obtained in group 1 – with lowered ability to understand words in the presence of competitive noise suggest that the subcortical section of auditory tract (inferior colliculus of the midbrain) may play a role for both BMLD and speech-in-noise comprehensiveness.

Group 2 was selected due to the characteristic result of speech audiometry in silence, where at least 30% speech discrimination loss was noted (SRS no more than 70%). Children of the group 3 had comparable normal speech understanding in silence and in noise and they differed from the group 4 (controls) only by the LLD presence.

In those groups (2, 3 and 4) the BMLD values were evidently higher than in group 1, yet without statistical significance. A slight difference in BMLD values between group 3 and controls in favor of the first one should be treated as accidental. However, the $SoN\pi$ values were markedly higher in children from group 1 than in the other groups. This proves that the patients from this group have not been so profoundly released from masking as those from other groups.

We did not go into the detail of the diagnosis of: "language/speech based disability/difficulties in school learning", originally made by a team composed of a psychologist, speech and language therapist. However, it should be worthy to note that in the study groups 1 and 2, to which we assigned patients with abnormal results of speech audiometry, there were twice as many boys as girls.

This confirms the observations of other authors concerning more frequent occurrence of auditory processing disturbances in males [11].

CONCLUSIONS

In conclusion, the results of this study show that in children with LLD, the lowered speech understanding in the presence of competitive signal corresponded to poorer results of BMLD test. In children with LLD and normal hearing in noise, BMLD did not show abnormalities. It may suggest that, in some children, non-auditory central processing disorders are the basis of this disease. The battery of central auditory processing tests should be included to evaluate the dysfunction of children with LLD.

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