Characteristics of fundamental laryngeal voice (f0) in developmental verbal apraxia

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Abstract

Objective. Developmental verbal apraxia (DVA), or developmental apraxia of speech is a motor speech disorder of motor programming and planning. Children with DVA have problems with saying sounds, syllables, and words. The aim of the study was to determine the characteristics fundamental of laryngeal voice in developmental verbal apraxia. Two parameters are observed: height and tension of voice. The research was conducted at the Institute for Experimental Phonetics and Speech Pathology and in the Institute of psychophysiological disorders and speech in Belgrade.

Methods. The sample consisted of 45 children ages 4-5 years. The first group (N=15) were children with diagnosed developmental verbal apraxia, the second group (N=15) children with diagnosed developmental dysphasia, and the third group (N=15) included children with diagnosed developmental phonological disorders. Groups were equalized in relation to age. The study was carried out individually.

Results. Qualitative analysis of the results showed that: for 20% of group with phonological disorders it is present low voice in the normal tension, and in 80% of children it is present normal height in a normal voice tension. In group with dysphasia 13.4% of children have a low voice in the normal tension, 66.6% of children have normal height and normal tension, and 20% of children have raised voice in a normal tension. In the group of children with developmental verbal apraxia, 26.6% of children have a low voice in the hypotension of the first degree, 6.6% of children have a low voice in normal tension, three children have low voice in hypertension of the second degree, 20% of children have elevated voice in hypotension of the second degree, 6.6% have increased voice in a normal tension, and 20% have elevated voice in the first degree of hypertension.

Conclusion. Results show that disturbances in height and tension of fundamental laryngeal voice are present in children with developmental verbal apraxia in a greater degree than in children with developmental dysphasia and developmental phonological disorders.

Key words: verbal apraxia, laryngeal voice, developmental dysphasia, developmental phonological disorders.

Introduction

Childhood apraxia of speech (CAS), or developmental verbal apraxia (DVA), or developmental apraxia of speech is a motor speech disorder caused by damage on areas of the brain that control the voice. It is caused by stroke, injuries during labour, and genetic disorders. Apraxia of speech is a disorder of motor programming and planning. Children with CAS have problems with saying sounds, syllables, and words. Reason for this is not muscle weakness or paralysis. The brain has problems in planning to move the body parts (e.g., lips, jaw, tongue) which are needed for speech. The child knows what he/she wants to say, but his/her brain has difficulty in coordination of the muscle movements which are necessary for saying those words. The severity of the voice fluency problem varies with the type of the brain damage. Patients have troubles with sequencing sounds and words. This is frustrating, as the patient knows what he/she wants to say, but is unable to coordinate his/her muscles to say the correct words. Replacement of words (house instead of hair), or non-words (her can) may come out instead. (http://www.livestrong.com/article/254867-about-voice-fluency-disorders/#ixzz1X8R5IzdR)

Apraxia of speech is a neurological condition affecting the development of a child’s speech. Apraxia is a neurological impairment in which are involved planning, executing, and motor sequenc-
ing movements. The National Institute of Health (USA) defines apraxia as a disorder of the nervous system. Apraxia is perhaps the most misunderstood of all the speech disorders. Verbal apraxia is a neurological motor speech impairment that involves a breakdown in the transmission of messages from the brain to the muscles in the jaw, cheeks, lips, tongue and palate that facilitate speech. There is no obvious weakness in these muscles, and a child may as well be able to move them quite normally when not trying to speak. Apraxic children, who are usually seen as “just late talkers” when young, are able to comprehend language at appropriate age level. However, they have difficulty in expressing themselves while speaking. With apraxia, a child knows what he/wants to say but there is a block in a pathway which is obstructing the signal from the brain to the mouth. For any child with a speech disorder, but especially with apraxia, the earlier therapy begins, results are better for the child and his/her social-emotional development. Verbal apraxia (VA) is a motor speech disorder that interferes with an individuals’ ability to correctly pronounce sounds, syllables, and words. It is a neurologically-based motor planning disorder of unknown cause. Verbal apraxia may occur as part of many neurological conditions, or may occur separately. Although the specific causes are unknown, possibilities include: direct result of neurological damage, as a complex neurobehavioral disorder (genetic, metabolic) and neurological speech sound disorder (speech delay, verbal apraxia).

Since the human voice is the only one that can simultaneously produce a word and tone, it is of particular importance in communication because it gives us a lot of information’s about a particular person, or of person’s sex, age, health, temperament, thoughts, feelings, moods, etc. The fundamental frequency / fundamental laryngeal voice (Fo) is an essential component of spoken voice, or the frequency with which the vocal cords vibrate. Pitch is a perceptual phenomenon, and depends on the fundamental frequency, which is a physical parameter. The fundamental frequency (Fo) is the number of vibrations that vocal cords make in one second, expressed in hertz (Hz) and is determined with the activity of internal laryngeal muscles, with subglotic pressure and tension, weight and length of the vocal cords, which is partly a consequence of cricoid, thyroid and arytenoid cartilages. Value of Fo is influenced with age, sex, physical condition, social environment, emotional, intellectual status, laryngeal pathology, mental disorders, hearing impairment, neurological and endocrine disorders and general health. The voice is not monotonous and is not constant, depends on the emotions, pace, intonation and volume, which means that affectivity follows our vocal and general behavior.

The main characteristics of voice are height, intensity and timbre. Subjectively, voice is estimated as: high, low, tight, rough, hoarse, beep, etc. This subjectivity can be verified by objective testing methods.

Voice changes are manifested in three basic features: the tone, intensity and timbre. In addition to basic, there are two more features of voice, amount of noise in the voice and the way to start a voice (of attacks).

Material side of each voice, according to Belic, represent the volume of voice and its tone: pitch or tone of voice, strength or tone of voice, timbre or tone, loudness and duration of voice or tones [2]. The main task of the vocal cords is to produce sound waves that interlocutor can hear. Vocal cords make clear high tones, and their height and intensity depend on the shape of the larynx, vocal cord length, tension, and speed of their flickering. All these features are changeable, and differ from person to person.

The sound obtained by relaxation vibration of the vocal cords, in whose rhythm the air current modulates, is called primary laryngeal voice. That sound is too weak and not audible. Final strength, audibility, volume and timbre are obtained by passing through the vocal tract, and resonant cavity when the voice occurs [2].

The main laryngeal voice occurs by vibration of vocal cords in the horizontal plane (by which is expiratory rhythmically interrupted). It is amplified with resonant processes and articulation (in resonant and articulation cavities), and modeled in the speech sounds. The phenomenon of resonance in the physical sense represents the increase of intensity of vibration when the frequency of external force that causes vibration, coincides with vibration frequency of their own systems [3].

In the acoustic image appear upper tones, i.e. harmonics, in addition to the basic tone. In humans, as a resonant cavity, are operating mainly oral and
nasal cavities, in the some parts pharynx and larynx, and in the wider sense, the whole head and chest. With movements of articulation organs (tongue, palate, lips, cheeks, laryngeal and pharyngeal anal sphincters), shape and size of the resonant space are changing, by which to some extent they enhance or suppress the basic laryngeal voice, thus giving the specificity of acoustic impression and image of generated voice/voices. The absence or occurrence of pathological resonant frequencies substantially changes the structure of speech, and by auditory perception are revealed advances in timbre, sonority and nasality of voice [4].

Insonation of the fundamental laryngeal voice in the higher harmonic tones, with vowels and consonants modulation, is performed by supraglottic structures of the larynx, pharynx, oral and nasal cavity; structures that represent the voice resonator [5].

Pitch is a perceptual phenomenon, and depends on the fundamental frequency, which is a physical parameter. The fundamental frequency (F0) is the number of vibrations that the vocal cords make in one second [6].

Modulation with vocal cord creates the sound which has features of the harmonious sound, by which are produced all vowels in the speech, and it has low intensity and is almost inaudible. Basic laryngeal voice when going through the resonant cavity increases and creates the harmonic tones that mark the voice [7].

Pitch depends on the speed of vibration of the vocal cords, or the fundamental frequency. Faster vibration creates a higher tone of voice, or a higher frequency. A speed of the vocal vibration depends on the thickness, length and tension of the vocal cords and air pressure that passes between the vocal cords. It is determined by the activity of internal laryngeal muscles, subglotic pressure and tension, weight and length of the vocal cords, which is also partly a consequence of the position of cricoids, thyroid arytenoid and cartilage [8].

One of the fundamental meanings of phonation is contained in this thought: "phonics is in the human development process, the result of an ingenious use of breathing mechanism for meaningful communication" [9].

Phonation or voice performance in the pharynx is part of the complex voice features, but at the same time its important element. The activity of the larynx is not equal in the performance of all voices. All vowels and consonants are created by vibration of adduced vocal cords, thus producing a basic laryngeal tone, while in unvoiced consonants role of the larynx is minimal, because vocal cords are and are not vibrating [10].

Generally when speaking about the phonation, it is meant of vocalization - the vocal performance in the pharynx. Phonics is defined as expiratory modified by laryngeal vibration and it occurs, according to recent findings in the following way: after prephonatory, willingly inspiration started, followed by prephonatory expiratory, vocal cords take the paramedial position which is triggered with nerve impulses which come in the laryngeal muscles with the upper and lower laryngeal nerve. With the same nerves are coming impulses, and with their action is changed the weight, length and tension of the vocal cord.

Partial obstruction of expiratory air currents is caused with Bernoulli effect: constant volume flow on the place where sudden narrowing appeared is achieved by increasing velocity, thus reducing pressure at the narrowing. Because of that pressure drops in the subglotic region, and vocal cords are inserted to the center line followed by complete obstruction of air flow. With this is increased the subglotic pressure which suddenly linger the vocal cords to paramedial position [11].

Such a process of horizontal vibration of the vocal cords lasts as long as the pressure is reduced below critical subglotic limits, which requires new prephonatory inspiration. Phonation only begins willingly. Later during phonation frequency of vibrations, or mass, vocal cord tension and length depend on the reflex control mechanisms, especially the kinesthetic mechanism [12].

Receptors located in the mucosa, muscles and joints of pharynx play an important role in controlling kinesthetic, as medulla oblongata is informed of any physiological and pathological irritation which appeared during phonation.

In normal phonation both vocal cords vibrate with the same frequency, amplitude and phase, i.e. at the same time are approaching the center line and moving away from it. Except horizontal vibrations [6], wave like motion of the vocal cords mucosa is an important part of the vibrating mechanism, as it is an expression of its structural cha-
racteristics, which provides the necessary features of a normal voice and ensures normal phonation. Value of Fo’s affected with age, sex, physical constitution, social environment, intellectual status, and laryngeal pathology, mental disorders, hearing impairment, neurological and endocrine disorders and general health. The voice is not monotone and not constant. Depends on the emotion in speech, pace, tone and strength. Our vocal and general behavior was followed with affectively.

Voice of the one person is not the same every day. Voice variations of one person, from day to day, can change in the range up to 18%. Faster vibration creates a higher tone of voice, or a higher frequency. Increased air pressure causes an increase in both intensity and a higher tone of voice. The average height of fundamental laryngeal voice is: the male 120-150 Hz, in women 180-220 Hz, in children around 300 Hz. [6].

Changing the basic laryngeal voice makes possible national prosody and speech. When listening to vocals, fundamental laryngeal voice is not heard. It is heard a complex acoustic wave which consists of a series of frequencies which develop with modulation of basic laryngeal voice in the pharynx, hypopharynx, oral and nasal cavity.

The tension of the voice is a muscle tension of vocal tract. They differ in two groups: laryngeal and supra laryngeal tensions that occur during phonation or articulation.

**Aim**

The aim of this study was to determine the basic characteristics of fundamental laryngeal voice (F0) with developmental verbal apraxia.

**Methodology**

The research was conducted at the Institute for Experimental Phonetics and Speech Pathology and in the Department of psycho physiological disorders and speech in Belgrade.

**The sample**

With adequate diagnosis conducted by an expert team: speech therapist, clinical psychologist, neurologist, it is performed a selection of children whose disorders in speech and language are diagnosed as a developmental verbal apraxia, developmental dysphasia and developmental phonological disorders. The sample consisted of 45 children, age between 4 and 5 years. The first group (N = 15) were children with diagnosed developmental verbal apraxia, the second group (N = 15) children with diagnosed developmental dysphasia, and a third group (N = 15) included the children with diagnosed developmental phonological disorders. The groups were equalized in relation to the age. The survey was conducted individually.

**Measuring Instruments**

**Test for assessment of basic laryngeal voice-laryngogram**

With laryngogram were observed properties of the voice in the correlation relation. This test covers four main fields and two scales that determine the tension and pitch. The tension has six level of possible deviations from normal, three indicating elevated (plus), and three reduced tension (minus).

**Pitch** also has six marks for deviation: three for the increased (plus), and three for a reduced height (minus). The first field in the central part of the laryngogram is a normal voice. At the first level of deviation, field labeled with number 1 is the first level of deviation from normal voice, and that field surrounds field of normal voice.

Deviation moves to the increase of the voice - plus position (1), or decrease of the voice - minus position (-1). Increased voice (1) is the result of the first degree (1) tension of the vocal cords, and low voice of minus position (-1). Thus, the high voice of the first degree (1) occurs in correlation with the tension of the first degree (1), and low voice of the first degree (-1) is correlated with first degree (-1) looseness.

At the second level of deviation, the second field of the laryngogram, which surrounds the first, imply second degree deviation such as: particularly increased voice in the plus position (2), or half whisper in minus position (-2). Particularly high voice (2) is the result of the tension of the second degree (2), and half whisper (-2) results from looseness in the second degree (-2). In the third degree of deviation, the third field is the largest; external field of the laryngogram. Third level of deviation is marked in it, i.e. highest
degree of dysphonic. Its correlates are in the plus position: tension of third level (3) leads to whistle voice (3), and minus position of the third level (-3) leads to a whisper (-3).

Marked voice features are on the left and bottom of the laryngogram. On the left are levels of intensity and on bottom are levels of height. Levels of intensity are entered in the squares observed by its vertical. Each of these analytical evaluations is crossed with its correlation, and gives a complete picture of fundamental voice.

In the corresponding squares are therefore entered as many labels as there are objections, and labeling is done by entering mark “x”, or hatching appropriate square field. Analysis of the primary voice by laryngogram is the roadmap for its correction.

Results and discussion

Childhood Apraxia of Speech (CAS) is present in children who have no evidence of difficulty with strength, or range of motion of the articulators, but are unable to execute speech movements because of motor planning and coordination disorders. This should not to be confused with phonological impairments in children with normal coordination of the articulators during speech.

In Table 1, are shown the results of tests obtained on the basis of fundamental laryngeal voice. Qualitative analysis of the results showed that:

1. group with phonological disorders - in 3 children (20%) in is present a low voice in the normal tension, and in 12 children (80%) normal pitch in normal tension,
2. group with dysphasia - 2 children (13.4%) have low voice in the normal tension, 10 children (66.6%) have normal height and normal tension, and 3 children (20%) increased tension in a normal voice,
3. group with developmental verbal apraxia – 4 children (26.6%) have a low voice in the first level hypotension, 1 child (6.6%) has a low voice in the normal tension, 3 children have low voice in the hypertension of second level, 3 children (20%) have raised a voice in the hypotension of second degree, 1 child (6.6%) has increased tension in normal voice, and 3 children (20%) have raised voice in the hypertension of first degree.

Many studies describe the disorders in the height of fundamental laryngeal voice in developmental verbal apraxia (a neurological disorder which is characterized by the inability of the execution of coordinated articulator movements, with the absence of muscle weakness and movement disorder of speech programming). From the etiological factors are singled out: genetic predisposition to motor coordination disorder, prenatal and natal causes, differences in speed or quality of myelination, neurological disorders, and later development of speech and language [13,14,15,16], but is not determined yet whether this is compensatory mechanism created as response to motor processing disorder [17]. It was found that dysphonic, noisy or hipper nasal voices are predominant. Disorders of height and tension of fundamental laryngeal voice are, in our study, present in children with verbal apraxia in a greater level than in children with developmental dysphasia and phonological disorders. This differs from the description of fundamental laryngeal voice in research dealing with differential diagnosis and phonological disorders verbal apraxia, where children with verbal apraxia have adequate voice quality, in comparison with children with phonological disorders, which, depending on the type of disorder have a hoarse, harsh voice and hipper nasal voice [13,14]

Conclusion

The results show that disorders of the height and tension of fundamental laryngeal voice present in children with developmental verbal apraxia are in a greater level than in children with developmental dysphasia and developmental phonological disorders.

Childhood Apraxia of Speech (CAS) is the term used most widely to describe difficulty in planning and programming speech movements in children. CAS is considered to be a neurological speech disorder that can occur by itself, along with other neuro-developmental disorders (such as autism), or due to accident or illness. CAS can range from mild to very severe. Children with apraxia of speech, in early stages of speech development, are likely to need intensive, individual, and frequent speech therapy in order to become intelligible speakers. According to the Childhood Apraxia of
Speech Association of North America, with proper help, children with apraxia of speech can make great strides in speech, language and communication with appropriate help, and in many cases they can achieve progress to the point that no one could tell that they had a severe speech disorder. However, often, other speech, language, and learning difficulties co-occur with this speech disorder. Childhood Apraxia of Speech (CAS) is present in children who have no evidence of difficulty with strength, or range of motion of the articulators, but are unable to execute speech movements because of motor planning and coordination problems. This is not to be confused with phonological impairments in children with normal coordination of the articulators during speech.
References


6. Hedjever, M. Fundamentals of physiology and speech acoustics, University of Zagreb, Faculty of Education and Rehabilitation-internal material, 2010.


16. Golubovic, S. Motoricki poremećaji govora/Motoric Speech Disorder: Fakultet za specijalnu edukaciju i rehabilitaciju, Univerzitet u Beogradu/Faculty of Special Education and Rehabilitation, University of Belgrade, Merkur/Mercur, Beograd/Belgrade, 2011.(In Serbian).


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