# Auditory Brainstem Response in Wave VI for the Detection of Learning Disabilities

M.Victoria García-Camba, and M.Isabel García-Planas

*Abstract*—The use of brain stem auditory evoked potential (BAEP) is a common way to study the hearing function of people, a way to learn the functionality of a part of the brain neuronal groups that intervene in the learning process by studying the behaviour of wave VI. The latest advances in neuroscience have revealed the existence of different brain activity in the learning process that can be highlighted through the use of innocuous, low-cost and easy-access techniques such as, among others, the BAEP that can help us to detect early possible neurodevelopmental difficulties for their subsequent assessment and cure. To date and the authors best knowledge, only the latency data obtained, observing the first to V waves and mainly in the left ear, were taken into account. This work shows that it is essential to consider both ears; with these latest data, it has been possible to diagnose more precisely some cases than with the previous data had been diagnosed as "normal"despite showing signs of some alteration that motivated the new consultation to the specialist.

*Keywords*—Ear, neurodevelopment, auditory evoked potentials, intervals of normality, learning disabilities.

## I. Introduction

THe ability to communicate through spoken and written language is one of the characteristics that distinguishes the human being. This skill is acquired and developed in the first years of life. For its correct evolution, a normal functioning of the auditory and visual capacity and an adequate environmental stimulus are required [1].

For there to be good communication, the integrity of the sensory receptors is essential. Human beings receive a multitude of stimuli through the senses that reach these receptors, continue through the neural transmission pathways and reach the brain areas where they are processed for recognition.

In this work, it has stimulated the acoustic sensory pathway by using the BAEP, and it has studied the response recorded at the cortical level represented by wave VI to discover early the existence of both cognitive and developmental disorders motor to perform the specific stimulation that contributes to the solution of the detected problem. Recall that, different studies suggest that, by measuring the hearing abilities of very young children, it could be determined much earlier who will be exposed to having learning problems ([2], [3]). Also, the auditory evoked potentials are been used to measure and monitor neurophysiological mtodifications of the central auditory nervous system, [4].

The sensory pathway has relay stations at both the peripheral and central levels, and it is in the last place where we have focused our study, specifically on the Medial Geniculate body and the auditory temporal cortex. Wave VI reflects the response of the sensory stimulus when it reaches the medial geniculate body and wave VII is the expression of the reaction when it comes to the cerebral areas (Figure 1) that constitute the auditory temporal cortex.

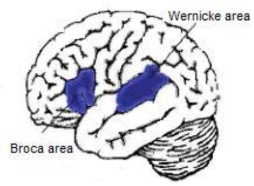


Fig. 1. Broca and Wernicke areas. Source [5]

Recall that the auditory pathway is made up of the following synaptic stations: the spinal ganglion of Corti, the ventral and dorsal cochlear nucleus, the medial geniculate body of the thalamus, and the auditory cortex, located in the temporal lobe, which is divided into primary and high school. During the process of spoken language [6], the primary auditory area is activated, phonetic analysis is performed in the superior temporal region and with the activation of a complex network located in the cerebral cortex of both hemispheres, the semantic analysis. Monaural stimulation activates a single pathway and binaural, helps to localize the signal. One way to measure the maturation of the neural fibres that make up the auditory pathway is through myelin, the functionality of which can be recorded through the latencies of the waves obtained in stimulation by auditory evoked potentials. Myelination begins between the sixth and seventh month of gestation and acquires its most significant development in the postnatal stage around five years of age.

Generally, the auditory pathway takes between 5 and 8 years to complete its maturation. For this reason, it has been selected a population of school-age children that coincides with this event. Despite everything, studies have indicated that the development (plasticity) of the sensory cortex is not restricted to a specific period but continue, although possibly to a lesser degree, throughout life [7]. Furthermore, as in [8] and [9], maturation and synaptic genesis are influenced by stimulation. Therefore, with adequate stimulation and the help of brain plasticity, certain learning disorders can be corrected.

Central auditory processing is defined as a set of specific skills necessary to be able to interpret what is heard. Its control is carried out through the auditory centres of the brainstem and through specific areas of the brain whose activity can be quantified through the recording of waves VI and VII of the BAEP. The different actions of auditory processing such as attention, discrimination, association, integration and response

M.V. García-Camba are with Clínica Corachan, Barcelona, Spain.
M.I. García-Planas is with the Department of Mathematics, Universitat Politècnica de Catalunya, Barcelona, Spain e-mail: (see https://futur.upc.edu/MariaisabelGarciaPlanas).

are influenced by anatomical, physiological, biochemical and socio-educational factors [10].

The existence of different brain activity in the learning process has been revealed with the latest advances in neuroscience and that can be observed through the use of non-invasive, low-cost and easily accessible techniques such as BAEP that can help to detect early possible neurodevelopmental difficulties for its subsequent assessment and cure. To date, only the latency data obtained has been taken into account, observing the first V waves and mainly in the left ear. This work shows that it is essential to take into account the latencies and amplitudes of both ears, with these latest data it has been possible to diagnose with greater precision some cases that with the previous data had been diagnosed as "normal "despite to show signs of some alteration that motivated the new consultation to the specialist.

This work is centred on in finding out what type of dysfunction occurs in the auditory cortex in patients who present some kind of disorder in order to detect some learning disability.

## II. Methodology

It is studied the alterations that occur in the central nervous system by studying the latency of wave VI that indicate cortical maturation in response to sound stimuli. As is known, variations in latencies and amplitudes are an indirect reflection of central auditory plasticity (see [11], among others).

Evoked potential (EP) is understood to be the neuroelectric response of the nervous system to a stimulus, more specifically it is a voltage fluctuation over time, generated by the nervous system in response to an appropriate stimulus. For the detection of evoked potentials, it is required to have graphic representations of waves that represent them. The concept of evoked potential (EP) tends to be confused with the concept of the spontaneous electroencephalogram. Unlike an (EEG), an EP collects the activity of the brain caused by an external stimulus, being, therefore, essential exposure to this stimulus.

The technique that has been used is the auditory brainstem evoked potentials (BAEP), which are the graphic expression of the response of the central nervous system to an acoustic stimulus, more specifically it is a voltage fluctuation over time, generated by the nervous system in response to an appropriate stimulus. The concept of evoked potential tends to be confused with the concept of the spontaneous electroencephalogram. Unlike an (EEG), a BEAP collects the activity of the brain caused by an external stimulus, being, therefore, essential exposure to this stimulus.

The BAEP's are composed of 7 waves that can be detected in the first 12 milliseconds after the start of the stimulation. Each wave is the expression of the neuronal response of a specific structure: wave I, from the proximal region of the eighth cranial nerve; wave II, from the cochlear nucleus; wave III, from the upper olive complex; wave IV, from the lateral lemniscus; wave V, from the inferior colliculus; wave VI, from the medial geniculate body; and wave VII, from the auditory temporal cortex.

The functionality of the late VI wave is the object of the study since, unlike the early waves, it has not been taken into account, and we have detected its relevance and possible clinical utility. By stimulating cortical areas with BAEP, dysfunctions can be located in specific regions of the auditory pathway at the brain level, which is the objective of the work.

The data collected from the waves is latency, which is a measure of the time used in processing the information and is measured in milliseconds, and the amplitude, measured in microvolts, indicates the concentration of attention of the subjects under study, reflecting the difficulty in discriminating different stimuli.

It is important to emphasize that the BAEP are a type of objective examination of the auditory and cognitive state of the patient that is not influenced by educational, social and cultural factors or by the physical condition of the patient or by her state of consciousness.

## III. Case of Study

Fifty patients between 5 and 8 years of age with a previous diagnosis were studied using data obtained from the first to five waves and whose result did not correlate satisfactorily with the clinical and cognitive data of the patients. This fact led us to go deeper into the study of these cases, complementing the previous data with others that could validate those already obtained and allow a more precise diagnosis, using wave VI values.

### A. Analysis of data

The study begins by collecting data on latencies and amplitudes in wave VI of the BAEP from both ears.

*1) Left ear:* From the latencies in wave VI, measured in the left ear of the 50 patients studied, It is analized their distribution about the normality intervals defined by Toro (1984), obtaining the following results:

66% of children are in the latency range $[7.08, 7.84)$, defined as the range of "normal"values, (Figure 2, a)).

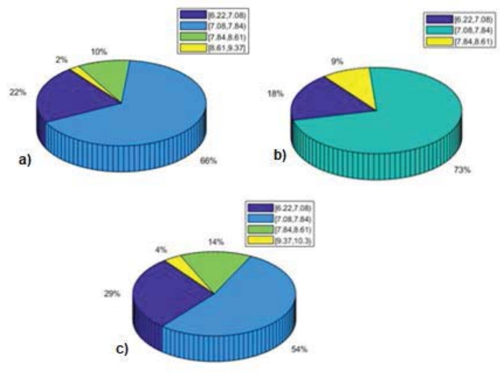


Fig. 2. Latencies distribution according [12]

Considering patients who have been diagnosed as "normal" or without disorders in the previous diagnosis, their distribution is as shown in Figure (2, b). It can be seen that 73% of patients have a latency that is in the normal range and the rest of the cases, the latencies are in the two adjoining intervals.

Taking into account only patients where some disorder have been diagnosed, the distribution is shown in Figure (2, c), in which it is observed that 54% of patients have their latency located in the normal range. This result suggests other possible partitions that given the scarcity of literature in this regard, we decided to redefine the normality interval.

To select a new, more reliable interval, it is analyzed the latency distribution shown in the bar diagrams (Figure 3).

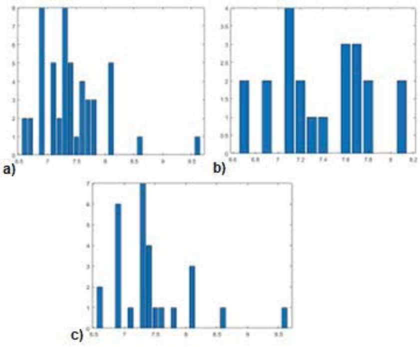


Fig. 3. Left ear latencies distribution a) all patients, b) "normal patients ", c) patients having some disorder

These data indicate that the normality interval to be considered is $[7.5, 7.8)$ and that the latency space is segmented as follows: $[6.0, 6.3)$, $[6.3, 6.6)$, $[6.6, 6.9)$, $[6.9, 7.2)$, $[7.2, 7.5)$, $[7.5, 7.8)$, $[7.8, 8.1)$, $[8.1, 8.4)$, $[8.4, 8.7)$, $[8.7, 9.0)$, $[9.0, 9.3)$, $[9.3, 9.6)$, $[9.6, 9.9)$, $[9.9, 10.2)$.

With this new segmentation, the patients are distributed as shows the Figure 4, where a) corresponds to all patients, b) the "normal"and c) patients with some disorder taking into account the latencies of I to V waves.

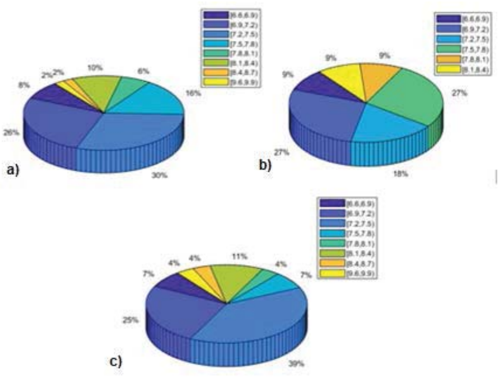


Fig. 4. Latencies distribution according new segmentation left ear

These graphs show that some patients (18%) whose previous latencies appeared as normal, when analyzing wave VI, are in the majority interval ($[7.2, 7.5)$) of patients with some disorder. Likewise, 27% of patients are within the range of patients with disorders ($[6, 9, 7.2)$).

This result leads to studying whether these patients diagnosed as normal may have some mild or undefined disorder. For this, it is necessary to continue analyzing the evoked potentials, to review the data of patients considered normal whose measurements of wave VI latencies have given results outside the range and compare them with the ranges of patients with some disorder and, also, analyze the results of the right ear.

*2) Review of results for normal patients with left ear out-of-range values:* Regarding the mode of latencies in wave VI of the left ear, depending on the type of disorder: learning disorder AT, attention deficit hyperactivity disorder ADHD, language disorder TL, autism spectrum disorder ASD, MRI motor delay, developmental disorder TD.

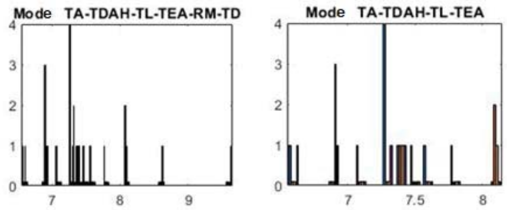


Fig. 5. Mode of latencies in wave VI of the left ear

Comparing the latencies of the patients classified as "normal" by their results in the previous waves, it has to that; in all these patients, hearing loss can be suspected without ruling out possible disorders. Specifically, patients with a latency of 8.1 could have a slight ADHD, although in one of the cases, reviewing the graph of the waves has probably been poorly valued, and its real value is 7.1 and could suffer a slight AT or MRI. Patients with values of 7.1 and 7.3 may have a slight TA. Patients having values lower than 7.1, may have a possible TL, and patients with a latency of 7.8 are on the border between AT and ADHD; which suggests the convenience of studying the latency of wave VII and those of the right ear.

*3) Right ear:* The latencies of the right ear have historically been very little studied; however, after analyzing the relationship between the results found in both ears, little correlation is observed in Figure 6.

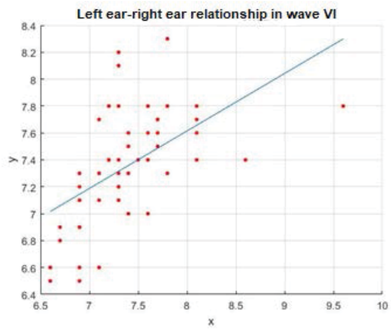


Fig. 6. Regression line

The equation of the regression line is $y = 0.4276x + 4.1943$ and its slope is $0.4276 < 1$. Therefore, the latencies of the right ear could provide complementary information to that given by the left ear.

When one observes the latency distribution (Figure 7), it is considered appropriate to define the "normal" interval as the same as for the left ear.

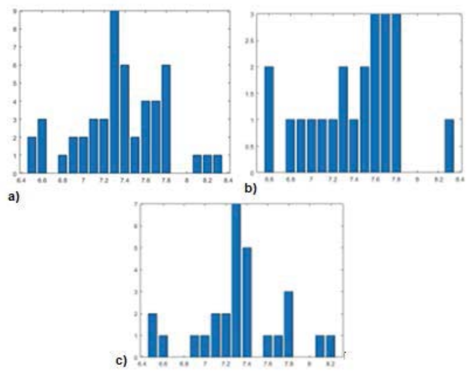


Fig. 7. Right ear latencies distribution a) all patients, b) “normal patients ”, c) patients having some disorder

The distribution of the patients according to the partition considered is showed in Figure 8 where a) corresponds all patients, b) “normal patients” and c) patients having some disorder.

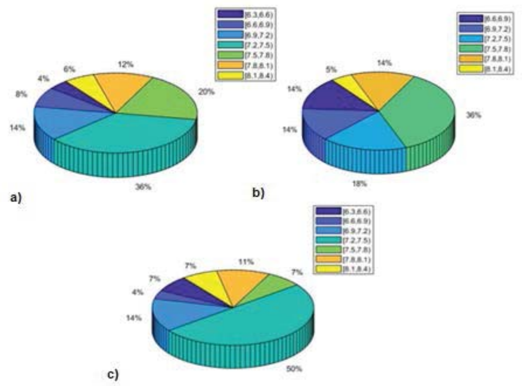


Fig. 8. Latencies distribution according new segmentation right ear

*4) Review of results for normal patients with right ear out-of-range values:* Comparing the latencies of the patients classified as “normal” by their results in the previous waves, we observe that in all these cases, hearing loss can be suspected without ruling out other possible disorders. Specifically, patient with a latency of 7.8 remains in the group of those affected by ADHD, which corroborates the result found in the left ear.

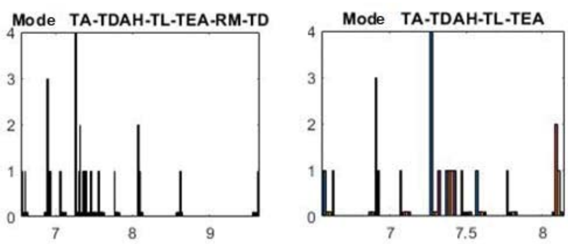


Fig. 9. Mode of latencies in wave VI of the right ear

It should be noted that patients with latency values in the right ear that are far from the “normal” range have also presented values that are far away and on the same side those obtained in the left ear, and although the values are not in the same range if they are in adjacent intervals, which allows corroborating the results found in the left ear.

### *B. Relationship with amplitudes*

The relationship between latencies and amplitudes in both the left and right ears for patients diagnosed with AT is analyzed below (see Figure 10)

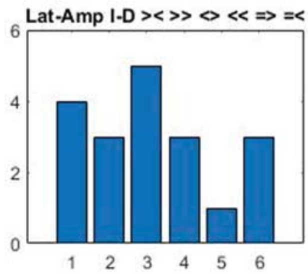


Fig. 10. relationship between latencies and amplitudes

Most patients with learning disability show a lower latency in the left ear than in the right, however a greater amplitude in the left ear than in the right

In the other hand, the analysis of the relationship of amplitudes obtained in wave VI for “normal” patients gives that all have a greater amplitude in the right ear than in the left ear, so the wave amplitude adds information for the diagnosis of a possible learning disorder, defining the type of disorder.

## IV. Discussion

During the action of perceptual learning, changes in synaptic connections occur in the sensory association cortex. Lesions of the inferior temporal cortex (upper level of the medial auditory association cortex pathway) impair auditory perceptual learning.

As has been verified with this work, this is manifested in an alteration in the appearance of VI waves. For this, the “normal interval”of wave VI latencies has been redefined. Have not been found enough studies in the literature, has had the need to standardize the values of VI wave that are related to the electroneurological characteristics of the same, that is, they are obtained in a tiny range of frequencies and can be modified by multiple factors.

Toro in [12], presents for wave VI latencies, an interval with an extensive range of normality, which makes it unfeasible for our study. As we have highlighted in the data analysis, with its normal range, many patients with disorders fell into it. The texts found in the literature regarding the use of the PEATC for the study of psychomotor, cognitive or other alterations or malformations (see [13], [14], [15] among others), have focused on the study of the latencies of the first five waves that indicate the functionality of the auditory pathway from the VIII cranial nerve to the inferior colliculus. All and that they have been able to detect some cases of learning disorder secondary to auditory dysfunction. In this study, the role of brain structures in cognitive processes has been studied in-depth, allowing the detection of alterations in cases of indemnity of the pre-cortical auditory pathway.

## V. Conclusion

A review of 50 children with no previous auditory pathology has been carried out, of which 22 had been diagnosed taking into account only the first five waves of BAEP, as "normal" from the cognitive point of view, and the rest with different neurodevelopmental disorders.

These children came to the medical consultation in search of answers to their problem not resolved with the previous diagnosis. Looking for this answer was when the need to analyze wave VI was seen and from which it was observed that it could give information.

Based on the abovementioned results, BAEP may provide pieces of information that help guiding the intervention process of students with Learning Disabilities.

## References

[1] WE. Nelson. *Tratado de Pediatría*. 9a Edición. México: Editorial Interamericana. 1986.

[2] M.I. García Planas, and M.V. García-Camba Vives. *Dyscalculia, mind, calculating brain and education*. In EDULEARN18: 10th Annual International Conference on Education and New Learning Technologies: Palma de Mallorca, Spain: July 2-4, 2018: proceedings book (pp. 0480-0489), 2018.

[3] M.V. García-Camba Vives, and M.I. García-Planas. *Neurociencia cognitiva y proceso de aprendizaje. Dislexia digital*. XXIII Reunió Anual de l'SCN, Barcelona, España, 2019.

[4] K.D.F. Alvarenga, E.S. Araújo, É. Ferraz, and P.A.P. Crenitte. *P300 auditory cognitive evoked potential as an indicator of therapeutical evolution in students with developmental dyslexia*. In CoDAS 25(6), pp. 500-505. Sociedade Brasileira de Fonoaudiologia. 2013.

[5] M.S. Gazzaniga, R.B. Ivry, and G.R. Mangun. *Cognitive neuroscience: The biology of the mind*. New York: Norton and Company, (2002).

[6] L. Ruytens, A. Willemsem, P. Van Dijk, H. Uit, F, Albers. *Imaging of the auditory system using PET*. Acta Otolaryngol.126(12), pp.1236-1244, (2006).

[7] S.C. Deoni, E. Mercure, A. Blasi, D. Gasston, A. Thomson, M. Johnson, and D.G. Murphy, *Mapping infant brain myelination with magnetic resonance imaging*. Journal of Neuroscience, 31(2), pp. 784-791. (2011).

[8] F.E. Musiek, J, Weihing, and J.B. Shinn. *Auditory Neuroscience*. Neuroimaging in Communication Sciences and Disorders, 193. (2007).

[9] A.G. García, and J.C. Fernández. *Neurofisiología del desarrollo y la maduración del sistema nervioso periférico*. Revista de neurología, 38(1), pp. 79-83, 2004.

[10] J. Bever. *Language and perception. Miller G. Communication, language and meaning*. New York: Basic Books Inc, 1973.

[11] M.V. García-Camba Vives, and M.I. García-Planas. Neurofisiología del proceso de escritura digital. Dislexia digital. XXIV Reunió Anual de l'SCN, Barcelona, España, 2020.

[12] J. Toro. (1984). *Potenciales evocados*, Acta Médica Colombiana 9(6), pp. 319-324, (2006).

[13] R.C Anderson, R.G Emerson, K.C. Dowling and N.A. Feldstein. *Improvement in brainstem auditory evoked potentials after suboccipital decompression in patients with Chiari malformations*. Journal of neurosurgery, 98(3), pp. 459-464, (2003).

[14] M. Gallardo, and C. Vera. *Estudio de la vía auditiva central por medio de las respuestas evocadas auditivas del tronco encefálico (ABR), en niños con retraso en el lenguaje*. In Anales de la Facultad de Medicina 64(1), pp. 27-33. UNMSM. Facultad de Medicina, 2003.

[15] E. Hernández-Zamora, and A. Poblano. *La vía auditiva: niveles de integración de la información y principales neurotransmisores*. Gaceta médica de México, 150(5), 450-460, (2014).

**María Isabel García-Planas** Received the PhD in Mathematics from Universitat Politècnica de Catalunya, Barcelona Spain, in 1995. She joined the Department of Mathematics at the Universitat Politecnica de Catalunya, Barcelona, Spain as associate professor in 1996. Her work had been centred on Linear Algebra, Systems and Control Theory and Neural Networks. She has authored over two hundred papers having been cited more than 700 times (more than 300 after 2015), and serves on the referee on numerous indexed scientific journals. She has been plenary Speaker in several International Conferences.

**María Victoria García-Camba** Graduated in Medicine and Surgery from the University of Barcelona in 1984 and Master in Cognitive Neuroscience from the Isabel I de Castilla International University in 2016, she also holds a Master's degree in Sleep: Physiology and Medicine from the University of Murcia in the year 2016 and in Medicine Evaluator and Medical Expertise, University of Barcelona in 2017. She practices her profession as an adjunct physician in the Department of Clinical Neurophysiology of the Corachan Clinic, also exercising her work as a neurologist at the Comprehensive Ophthalmological Institute. Currently, her research is focused on neuroscience and learning difficulties.