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The Latency-Amplitude Binomial of Waves Resulting from the Application of Evoked Potentials for the Diagnosis of Dyscalculia

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Abstract—Recent advances in cognitive neuroscience have allowed a step forward in perceiving the processes involved in learning from the point of view of acquiring new information or the modification of existing mental content. The evoked potentials technique reveals how basic brain processes interact to achieve adequate and flexible behaviours. The objective of this work, using evoked potentials, is to study if it is possible to distinguish if a patient suffers a specific type of learning disorder to decide the possible therapies to follow. The methodology used in this work is to analyze the dynamics of different brain areas during a cognitive activity to find the relationships between the other areas analyzed to understand the functioning of neural networks better.

Also, 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 non-invasive, innocuous, low-cost and easy-access techniques such as, among others, the evoked potentials that can help to detect early possible neurodevelopmental difficulties for their subsequent assessment and therapy.

From the study of the amplitudes and latencies of the evoked potentials, it is possible to detect brain alterations in the learning process, specifically in dyscalculia, to achieve specific corrective measures for the application of personalized psycho-pedagogical plans that allow obtaining an optimal integral development of the affected people.

Keywords—Dyscalculia, neurodevelopment, evoked potentials, learning disabilities, neural networks.

I. Introduction

The Association "American Psychiatric Association (APA, 2017)" describes dyscalculia as a specific and complex learning disorder that affects basic number processing and mathematical learning. It has an approximate prevalence of between 3% and 6% [1]. Despite its not inconsiderable incidence and similar prevalence concerning dyslexia or other learning difficulties, much less attention has been devoted to it. Dyscalculia can occur in association with other neurodevelopmental disorders such as dyslexia, or attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD) and autism spectrum disorder (ASD). Co-occurrence is generally assumed to be a consequence of risk factors that are shared between disorders, such as working memory. However, it should not be assumed that all schoolchildren affected by dyslexia have problems with mathematics, although the percentage may be very high, or that all schoolchildren affected by dyscalculia have difficulties with reading and writing. This last co-occurrence rate could well be a much lower percentage. The aetiology of Specific Learning Disorders is multidimensional since both neuropsychological factors, learning processes, and socio-cultural factors are involved [2].

The detection of people with learning difficulties in mathematics, who at the time of the study were not diagnosed, or incorrectly diagnosed or well diagnosed in adulthood with the consequent problem of social exclusion that this has entailed, has motivated this job. Persistent difficulties in learning mathematics and, also, in reading (dyslexia) are, due to their relevance and prevalence, the two most important learning disorders in both educational and clinical practice.

For a correct diagnosis, it is essential to know the functioning of the cerebral neural circuits that intervene in the generation of numerical and mathematical processing (whose alteration causes dyscalculia). This knowledge has been clearly, increased by advances in the development of new techniques for visualization and functional brain analysis that allow studying the brain regions and circuits that are activated during arithmetic operations.

The arithmetic calculation is a complex multimodal neurocognitive function closely linked to other cognitive processes such as language, executive functioning, spatial structuring, and memory. Numerous areas of the human brain are involved in computational capacity, forming neural networks; for this reason, different lesions in the brain can produce calculation disorders, [3], [4].

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 they are processed for recognition.

The analysis of the records of modifications of the electrical potential produced by the nervous system in response to external stimulation, in this case of a visual and auditory type, allows diagnosing neurological disorders, through the reactions that these stimuli provoke in the different brain regions, observing the alterations in the amplitudes and latencies of the different constitutive waves of the evoked potentials.

Despite all the advances, the biggest problem is figuring out exactly what parts of the brain are activated when it realize arithmetic for people with and without learning disabilities. It is not easy to locate mathematical knowledge in the brain because different circuits can act partially autonomously. It is, therefore, a question of making progress in this regard.

In order to accomplish the objective to give some answers,

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in this work, the possibility of stimulating the auditory sensory pathway by using the auditory brainstem evoked potential (BAEP) has been considered, studying the response recorded at the cortical level represented by waves VI, among others, to discover early the existence of both cognitive disorders to perform the specific stimulation that contributes to the solution of the detected problem.

It is well known that the sensory pathway has relay stations at both the peripheral and central levels, and it is in the last place where it has focused the study, specifically on the Medial Geniculate body origin of the wave VI.

In this work, the interest is to differentiate the different kinds of learning disabilities disorders using evoked potentials.

II. Methodology

Most of the studies carried out show the different brain areas that are activated in the face of mathematical skills of the high level of difficulty in mathematicians [5]. However, the interest is focused on studying how the brain is activated against mathematical skills in people with dyscalculia.

A suitable mechanism for detection is the application of techniques for exploring brain activity in the presence of external and/or endogenous stimuli that will serve to establish specific intervention strategies to try to rehabilitate, to a greater or lesser degree, the affected functions and optimize and empower those that are least affected. For this, the evoked potentials technique is used, which are electrophysiological responses to certain stimuli. This technique is affordable, safe and inexpensive, and it can highlight how basic brain processes interact with each other to achieve appropriate and flexible behaviours. That allows for elaborating satisfactory responses to situations that an individual faces, particularly to conditions that present attentional problems derived from learning difficulties related to calculation.

The alterations that occur in the central nervous system by examining the latency and amplitudes of wave VI obtained have been studied, and that indicate cortical maturation in response to stimuli.

As is known, variations in latencies and amplitudes indirectly reflect central auditory plasticity (see [6], among others).

The graphic expression of BAEP as response of the central nervous system to an acoustic stimulus shows the 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 interest of the study is the brain functionality from the medial geniculate body.

This study is related to the functionality of the late VI wave since, unlike the early waves, recently it has been detected its relevance and possible clinical utility [7].

By stimulating cortical areas with BAEP, learning disorders can be located in specific regions of the auditory pathway at the brain level, which is the objective of the work.

III. Case of study

Fifty patients between 5 and 8 years of age who has been diagnosed were studied using data obtained from wave VI, in which distribution of latencies according to indicated equidistant intervals is showed in Fig. 1, Fig. 2.

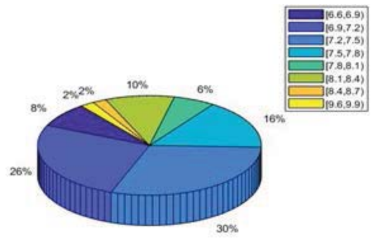

Fig. 1. Distribution of latencies OI

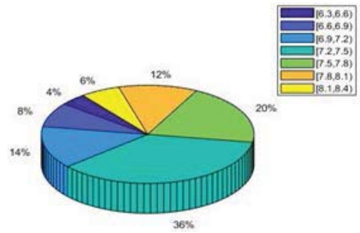

Fig. 2. Distribution of latencies OD

Remark: The “normal” patients are those which latencies found in the interval $[7.5, 7.8)$.

From these it has been selected the patients presenting symptoms of some learning disabilities.

A. Analysis of data

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

First of all, the regression lines comparing latencies of both ears are presented, in Fig. 3 for patients with a learning disorder and in Fig. 4 for “normal” patients.

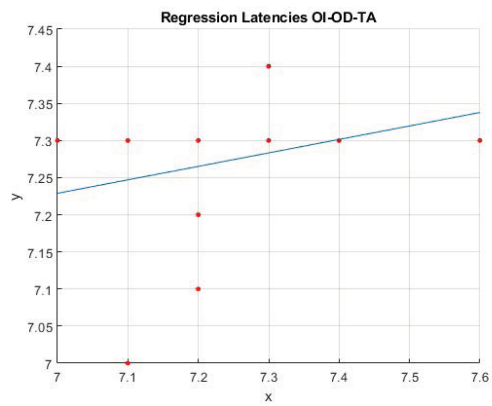

Fig. 3. Regression line latenties OI-OD TA

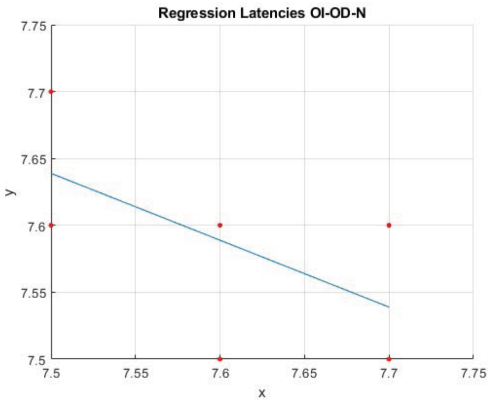

Fig. 4. Regression line latenties OI-OD N

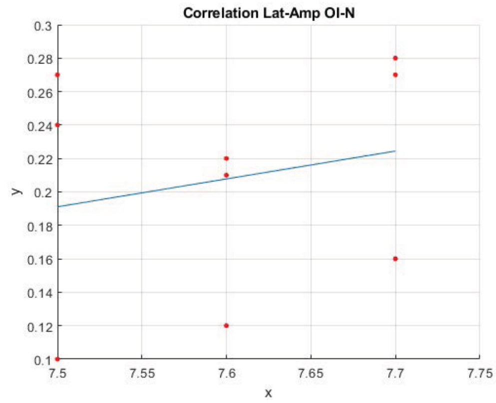

Fig. 6. Regression line Latencies-Amplitudes OI, Normal patients

1) Left ear: The interest is focused on relating latencies to amplitudes, and the regression lines comparing latencies with amplitudes in wave VI concerning the left ear are presented.

Firstly the regression line corresponding to the patients diagnosed with a learning disorder and concerning the left ear is given in Fig. 5.

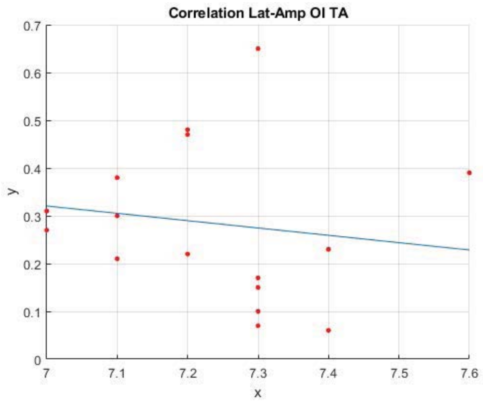

Fig. 5. Regression line Latencies-Amplitudes OI, TA patients

The equation of the line is $y = -0.1534x+1.3944$, where it is observed that the slope is negative, so there is a slight inverse dependence between both variables. The correlation coefficient is $r = -0.1410$, and this value is close to 0, indicating very little association between the two variables. The fact that it is negative means that as the value of one variable increases, the value of the other decreases.

The little relationship between variables indicates that both should be considered.

The regression line corresponding to the "normal" patients to respect left ear is given in Fig. 6.

The equation of the line is $y = 0.1667x - 1.0589$; in this case, the slope is positive, detecting a slight direct dependence between latencies and amplitudes.

The correlation coefficient is $r = 0.2159$; this value close to 0 indicates very little association between the two variables, although this relationship is, in absolute value, higher than in the case of patients with some learning disorder. The fact that it is positive indicates that as the value of one variable increases, the other's value also increases.

Although there is little relationship between variables, and it indicates that both should be considered, a connection is observed compared to cases with some disorder.

2) Right ear: Concerning the right ear, the regression line corresponding to the patients diagnosed with a learning disorder and about the right ear is given in Fig. 7.

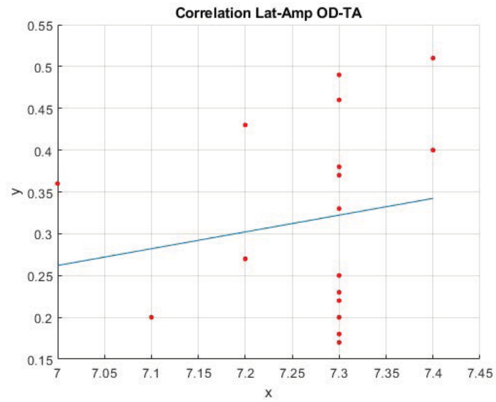

Fig. 7. Regression line Latencies-Amplitudes OD, TA patients

The equation of the line is $y = 0.2007x - 1.1430$, and the slope of the line is positive, detecting a certain direct dependence between latencies and amplitudes. The correlation coefficient is $r = 0.1722$; This value is close to 0, indicating very little association between the two variables. The fact that it is positive demonstrates that as the value of one variable increases, so does the value of the other.

The regression line corresponding to the "normal" patients to respect left ear is given in Fig. 8.

The regression line equation is $y = 0.6614x - 4.6857$, and the slope is positive, detecting a direct dependence between latencies and amplitudes. The correlation coefficient is $r = 0.3778$; this value, although closer to zero than one indicating a little association between the two variables, but it is much higher than in the case of patients with some learning disorder, and it is also higher than the results found for the left ear. The

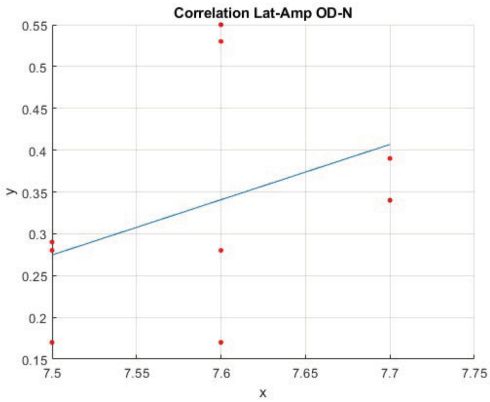

Fig. 8. Regression line Latencies-Amplitudes OD, Normal patients

fact that it is positive indicates that as the value of one variable increases, so does the other's value.

The relationship between latencies and amplitudes in both the left and right ears for patients diagnosed with AT is analyzed below (see Fig. 9).

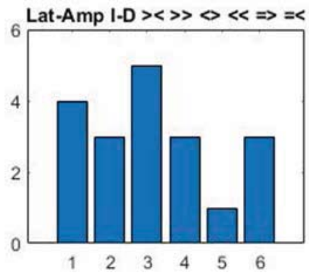

Fig. 9. Relationship between latencies and amplitudes

Precisely, column 1 corresponds to patients whose latency in the left ear is greater than that of the right (Lat LE $>$ OD); However, the amplitudes have the opposite relationship, that is, that of the left ear is less than that of the right (Amp LE $<$ OD). Using this nomenclature, the rest of the columns correspond to 2- Lat OI $>$ OD, Amp OI $>$ OD, the column 3- Lat OI $<$ OD, Amp OI $>$ OD the column 4- Lat OI $<$ OD, Amp OI $<$ OD, the column 5 Lat OI = OD, Amp OI $>$ OD and finally column 6. Lat OI = OD Amp OI $<$ OD.

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.

On the other hand, the analysis of the relationship of amplitudes obtained in wave VI for "normal" patients give 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.

Analyzing the results obtained in patients diagnosed with dyslexia and dyscalculia can observe (see Fig. 10) that the relationship between the amplitudes obtained in both ears in wave VI differentiates both learning difficulties.

It should be noted that in a study carried out using P300 evoked potentials; it was also observed that the amplitudes allowed differentiating dyscalculia from other types of learning

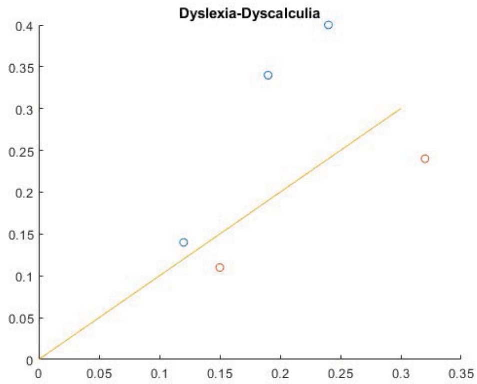

Fig. 10. Comparing amplitudes results between dislexia and discalculia

disorders [8].

IV. Discussion and Conclusions

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, it 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.

The texts found in the literature regarding the use of the PEATC for the study of psychomotor, cognitive or other alterations or malformations (see [9]-[11] 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

The amplitudes and latencies in the EP's must be taken into account to understand the arithmetic processing and brain compensation mechanisms in patients with learning disorders in general and dyscalculia in particular.

The alterations in the values of latencies and amplitudes concerning the mean that define the cases considered within the physiological limits in the BAEP tests allow distinguishing between other disorders, patients with learning disabilities.

The study of the anatomical-functional alterations present in learning disorders and dyscalculia is essential to achieve neuromodulation therapies that, through good brain plasticity, allow neuronal adaptation to correct the detected alterations and achieve techniques aimed at improving the functioning of dysfunctional brain areas.

The results obtained are the starting point for implementing specific corrective measures both from the perspective of neuroscience and educational intervention. The evolutionary follow-up is essential, carrying out new tests to evaluate the effects of the therapeutic program.

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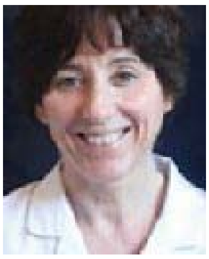

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