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RESEARCH ARTICLE

Lexical tonal discrimination in Zapotec children. A study of the theta rhythm



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KEYWORDS

Tonal-languages;
Zapotec;
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Electroencephalogram;
Theta rhythm;
Theta relative power

Abstract

Background: Zapotec is a language used mainly in the state of Oaxaca in Mexico of tonal characteristic; homophone words with difference in fundamental frequency with different meanings. Our objective was to analyze changes in the electroencephalographic (EEG) theta rhythm during word discrimination of lexical tonal bi-syllabic homophone word samples of Zapotec.

Methods: We employed electroencephalography analysis during lexical tonal discrimination in 12 healthy subjects 9-16 years of age.

Results: We observed an increase in theta relative power between lexical discrimination and at rest eyes-open state in right temporal site. We also observed several significant intra- and inter-hemispheric correlations in several scalp sites, mainly in left fronto-temporal and right temporal areas when subjects were performing lexical discrimination.

Conclusions: Our data suggest more engagement of neural networks of the right hemisphere are involved in Zapotec language discrimination.

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PALABRAS CLAVE

Lenguajes tonales;
Zapoteco;
Discriminación tonal
léxica;
Electroencefalograma;
Ritmo theta;

Discriminación tonal léxica en niños zapotecas. Un estudio del ritmo theta

Resumen

Introducción: El zapoteco es un lenguaje hablado principalmente en el estado de Oaxaca, en México, que tiene la característica de ser tonal; es decir, las palabras homófonas que difieren en la altura del fundamental tienen diferente significado. El objetivo de este trabajo fue analizar los cambios del ritmo theta del electroencefalograma en el curso de la discriminación de palabras bisilábicas homófonas en zapoteco.

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Potencia relativa theta

Método: Se empleó el análisis espectral del electroencefalograma durante la discriminación tonal léxica del lenguaje zapoteco en 12 niños sanos de 9-16 años.

Resultados: Se observó una mayor potencia relativa theta en la región temporal derecha durante la discriminación léxica en comparación con el registro de reposo-ojos abiertos. También se observaron varias correlaciones significativas intra e interhemisféricas con predominio entre la región frontotemporal izquierda y temporal derecha mientras se realizaba la discriminación tonal léxica.

Conclusión: Estos resultados sugieren que hay un mayor compromiso de las redes neuronales en el hemisferio derecho que participan en la discriminación del lenguaje zapoteco.

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1. Introduction

Analysis of non-tonal languages depends on different neural circuits formed by heritage and experience during early childhood and engage mainly temporal and frontal areas of the left hemisphere.¹ In tonal languages, discrimination of homophone words depends on pitch of fundamental frequency for lexical meaning. Lateralization for phonetic and semantic analysis has been investigated in adult native speakers of Mandarin. Magneto-encephalography (MEG) recordings indicate that hemispheric asymmetry in temporal and temporo-parietal regions was reduced during sensory processing discrimination of words.² However, to date, no studies have been undertaken looking for brain lateralization in Zapotec.

The Zapotec language belongs to an ancient linguistic family of tonal-language group spoken in Mexico and called Otomangueans. At present, Zapotec language is in danger of extinction; thus, there is an urgent need to study its neurophysiological characteristics. As in other tonal-languages, lexical meanings are established when the word sounds are contrasted with the direction of the F0. Inter-syllabic excursions among homophone words are taught to infants and children in Zapotec homes and schools. It was postulated that at some time during development an originally bilateral activation of several brain areas by lexical-tone perception would be lateralized to one or the other hemisphere;³ however, this fact is unknown.

Techniques for assessing brain organization include functional magnetic resonance image (fMRI) and electroencephalography (EEG) among others. EEG recordings allow the assessment of synchronized neuronal activities for analysis in the frequency domain. Theta rhythm of the EEG has been related to several cognitive processes such as language processing,⁴ auditory perception,⁵ and others. Thus, our objective in this investigation was to analyze changes in the theta rhythm in several areas in the course of word lexical tonal discrimination (LTD) of bi-syllabic word samples of Zapotec spoken in Oaxaca, Mexico.

2. Methods

2.1. Subjects

We studied six healthy female and six healthy male children from an elementary school (age range 9-11 years) and

six healthy female and six healthy male teenagers from a high school (age range 12-16 years) from Juchitán City. Clinical, neurological, audiometric and visual tests were performed in all subjects and did not reveal alterations. All subjects were right-handed according to the Edinburgh questionnaire⁶ and attended school in classes conducted in Zapotec along with some conducted in Spanish, but the subjects were functionally monolingual native speakers. Children and their parents were informed about the research objectives and signed informed consent according to the Helsinki Declaration. The Research and Ethics Committees approved the protocol.

2.2. Zapotec-language test samples

Zapotec speech samples were recorded at the Acoustics Laboratory of the Center for Applied Sciences and Technological Development and at the Psychoacoustics and Phonetics Laboratory of the National School of Music (National University of Mexico). An adult native Zapotec speaker who was a teacher and commentator at a local radio station (with adequate and very understandable speech) provided the samples and the translation into Zapotec of the instructions for the psychological and psychoacoustic tests. Samples were presented in free-field in a quiet room utilizing a Sony cassette recorder and player with a comfortable sound level (between 55 and 65 dB).

2.3. Psychological tests

We used the Free Human Figure Drawing test to measure cognitive and emotional maturation.⁷ Raven Colored Progressive Matrices for Children was employed for testing general non-verbal intelligence in children from the elementary school.⁸ The Rey-Osterrieth Test of Copying and Reproducing Complex Geometric Figures⁹ and the Raven Standard Progressive Matrices Test¹⁰ were utilized for testing visual perception, long-term visual memory, and general intelligence, respectively, in the group of high-school subjects. Subjects were tested one by one while comfortably seated. Results were evaluated by a certified psychologist.

2.4. Psychoacoustic tests

LTD test was utilized.¹¹ The test consists of two parts related to the discrimination and perception of lexical tones of

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