Visual and Auditory Event-Related Potentials in Poor, Good, and Dyslexic Spanish Readers.

José A. Adrián (PSICOLOGIA@uma.es)
Facultad de Psicología de la Universidad de Málaga;
Campus de Teatinos, s/n.
29071- Málaga (Spain)

María C. Pérez-Ábalo (PSICOFIS@cneuro.edu.cu)
Centro de Neurociencias de Cuba;
Ave. 25 y calle 158, Cubanacán, Playa;
Ciudad de La Habana (Cuba)

Armando Piñeiro (PSICOFIS@cneuro.edu.cu)
Centro de Neurociencias de Cuba;
Ave. 25 y calle 158, Cubanacán, Playa;
Ciudad de La Habana (Cuba)

Alfredo Espinet (ESPINET@uma.es)
Facultad de Psicología de la Universidad de Málaga;
Campus de Teatinos, s/n.
29071- Málaga (Spain)

Abstract

This study presents the results of investigating visual and auditory ERPs in three different groups of Cuban and Spaniard child readers (Poor, Good, and Dyslexics). ERPs N400 and N450 were recorded to evaluate semantic and phonolgical access during lexical and rhyme decision tasks. Data showed latency differences for N400 and N450 between two of the groups studied. Lexical and Non-lexical strategies are considered to explain the main differences found. We conclude by underline the importance of this kind of psychophisiological exploration for helping specialists to neuropsychological evaluation and diagnosis of child reading impairment.

Introduction

Electrophysiological research into ERPs is slowly beginning to open functional doors to science, allowing us to better understand certain brain processes involved during human cognition. The interdisciplinary marriage between cognitive psychology and psychophysiology has begun to bear fruit in recent years as was foreseen in (Coles, 1989). In this respect, psycholinguistics and neuropsycology have proven to be very fertile fields of research.

The relationship between certain linguistic processing tasks and specific electrophysiological components (peaks) has been pointed out by several authors. Kutas and Hillyard (1980) found that the N400 component was related to the capacity of a subject to detect semantic incongruity in mismatch trials during word-pair matching tasks (for review purposes on this ERP see Kutas and Van Petten, 1988; Osterhout & Holcomb, 1995).

On the other hand, other researchers have observed the existence of a similar negative onset and peak (called N450) occurring later during mismatch trials of rhyming word-pair. This task has been related to phonological processing (Rugg, 1984; Barret and Rugg, 1987). However, it remains unclear whether N400 and N450 are EEG components reflecting identical or different cognitive processes at different times. The detection of both components has been carried out by using drawings (Barret and Rugg, 1990a, 1990b), although only N400 has been described for the case of using spoken words as stimuli (McCallum, Farmer, and Pocock 1984; Holcomb and Neville, 1990; Bentin, Kutas, and Hillyard, 1993).

The idea that there are electrophysiological components which reflect the differential activity of both processes (semantic and phonological) has already been studied by various authors, although the peak latency related to phonological processing was situated between 270 and 370 msec. (Connolly and Philips, 1994).

The present work tests differential linguistic processing in two modalities (auditory and visual) from a psychophysiological standpoint. The use of N400 and N450 latencies instead of their amplitudes, more usual among the researchers in this topic, could give us useful information about the time course of semantic and phonological code activation. The characteristics of the groups involved (poor readers, good readers, and dyslexic) can supply clues as to the different ways of processing words (oral and written).

Method

Subjects

Twenty-five children with a mean age of 10.5 years (range : 10-12, SD = 0.85) were tested. The sample was divided into three groups: Group 1 was made up of 14 garden-variety poor readers who had a low-normal IQ (mean = 81.9, SD = 5.2) and, following the Peabody Picture Vocabulary Test, a verbal age lower than their chronological age (mean = 9.3 years, SD = 1.27); therefore, whith no discrepancy between IQ and reading age. Three children with developmental dyslexia formed Group 2 and were diagnosed as such out of a group of 30 poor reader children evaluated through a Battery of Computerised Reading Tests (BTL in the original Spanish version) standardised with Spaniard and Cuban populations. The dyslexic children had a normal IQ (mean = 103.66, SD = 7.57), with no discrepancy between their verbal and chronological age, but with a difference of more than 15 IQ points in favour of manipulation tasks versus verbal ones. Group 3 was formed by 8 good readers with a normal IQ and a verbal age superior to their chronological age (mean = 11.11 years, SD = 1.05).

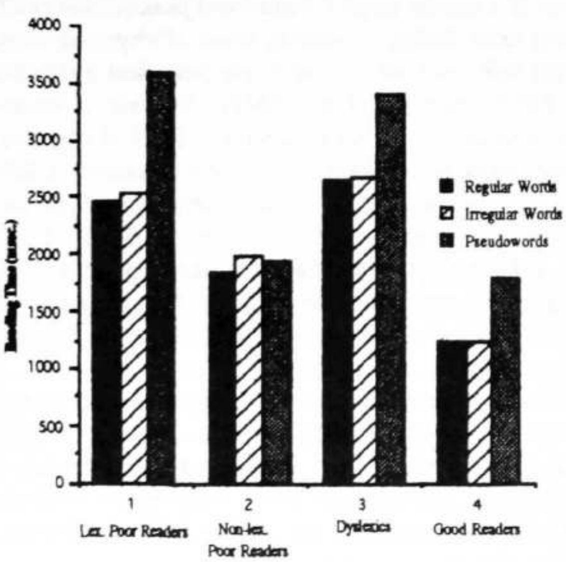

Figure 1: Reading Time by Group.

Procedure

As before, Battery of Computerised Reading Tests (BTL in the original Spanish version) was used to determine the reading age of the children in each group and to explore reading words and pseudowords (see Fig.1). The Group 1 (garden-variety poor readers) had a lower reading age than their chronological age (mean = 7.79, SD = 5.1), while the dyslexic children with a high IQ were between 3 to 4 years behind in reading. The good reader children had a reading age similar to their chronological age.

In Group 1 (garden-variety poor readers), 6 children (sub-group I) showed an advantage for reading words versus pseudowords. They read words faster and with fewer errors than pseudowords (lexical reading pattern). By contrast, the remaining 8 children (sub-group II) from Group 1 read words and pseudowords at a similar speed and score of errors (non-lexical reading pattern). All the children in Groups 2 (dyslexic) and 3 (good readers) presented a lexical type reading pattern for words and pseudowords.

Event-Related Potentials (ERPs) N400 and N450 were recorded in visual and auditory mode in schoolchildren. To obtain N400 we presented 80 pairs of semantically associated words (furniture-table) and 80 pairs of semantically incongruent words (fruit-piano). To obtain N450 we presented 80 pairs of rhyming words (like seven-heaven [*niña-piña* in the original Spanish]), and 80 non-rhyming pairs (like pencil-ruler [*casa-pelo* in the original Spanish]). These were two-syllable words and had a high frequency of use in Spanish (mean frequency = 44 per million). For visual modality (printed words), each sequence consisted of identical 80 pairs like auditory modality, presented at the center of a VGA computer monitor, with white letters on a black background. The letters subtended a vertical visual angle of 0.83° and horizontal visual angle of 0.43°.

Visual and auditory components N400 and N450 were explored for each child. In the matching tasks, two randommized sequences of stimulus pairs were presented, one for each task.

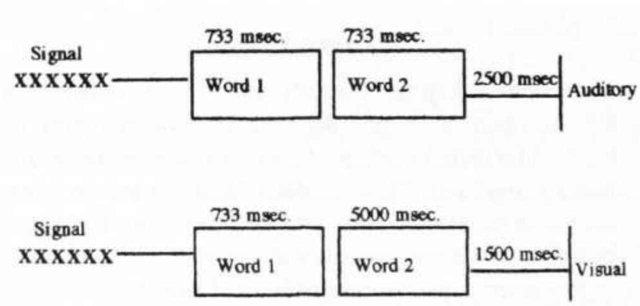

Figure 2: Experimental Paradigm.

The subjects had to detect the 50% of the pairs in wich the two stimuli were closely associated in meaning in the semantic task, or the 50% of the pairs which rhymed in the phonological task. Same decision tasks (semantic and phonological) with pairs of words were tested in all three groups. Idiomatic words differencies between Cuban and Spaniard samples were considered in the experiment. The two stimuli in a pair were presented sequentially. The stimuli were presented with a digital sound reproduction system to the subjects binaurally and via earphones at a comfortable intensity level. Figure 2 shows experimental paradigm used for recording ERPs N400 and N450.

The electroencephalographic (EEG) activity was recorded with a MEDICID III/E system from twenty sites of the international 10/20 system; although only activity from Cz will be reported here. Disk Ag/AgCl electrodes were used and inter-electrode impedeance was kept below 5 kOmh. Linked earlobes were used as reference and the forehead was grounded. Two bipolar derivations were used to monitor the horizontal and vertical electro-oculogram (EOG). The EEG after amplification and filtering (from 0.5 to 30 Hz, -3dB points) was digitized (12 bit converter). Digitalization was synchronized with the onset of the second stimulus in each pair, with a sampling period of 4 msec., and was stored on magnetic disk for off-line analysis.

A total of 1024 msec. were recorded on each trial, with a 100 msec. pre-stimulus window. Each EEG segment was visually inspected and those with artifacts, eye movements or with incorrect responses were eliminated.

For every subject, averaged ERPs were obtained (and smoothed) for match and mismatch trials. Three quantitative indicators of signal to noise were measured (CCR, SDR and RNL). Cases with inadequate values of these indicators were replaced. All data points were corrected by substracting the average pre-stimulus amplitude value.

Two independent judges measured onset, and peak latencies of N400 and N450 at Cz site, and in each individual difference wave-form (mismatch ERP minus match ERP) by visual inspection, and the average of the two observations was used in subsequent analysis. Additionally, the time regions in which there were statistical differences (across the sample of subjects) between match and non-match ERPs were calculated for each task and stimulus modality Cz, For this purpose, permutation techniques were applied to the t-tests comparing match and mismatch ERPs for each time point in a region within 100 and 750 msec. Ensemble onset was defined as the first time point after five consecutive significant values.

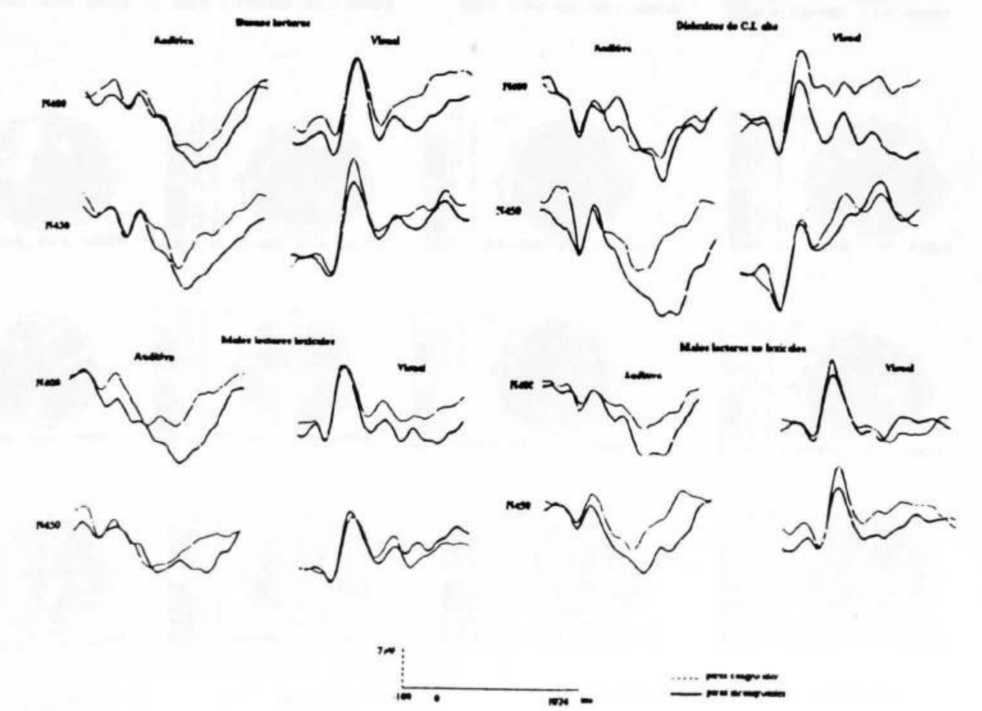

Figure 3: Auditory and Visual Grand Average ERPs at Vertex (Cz) for semantical (N400) and phonological (N450) matching tasks in each group and sub-group (lexicals vs. non-lexicals) of subjects.

Results

Electrophysiological profiles and their corresponding mapping are presented in Figs. 3 and 4. The grand average obtained for N400 and N450 in visual and auditory modes are shown for each group (see Fig.3). The electrical distribution activity for each group (Good, Poor, and Dyslexic) and sub-groups of Poor reader group (garden-variety poor readers: lexical pattern, and non-lexical pattern) are mapped in Figure 4.

Significant N400 and N450 components were confirmed both in auditory and visual mode (spoken words and printed words) in the control good reader group. For the spoken words, phonological access occurs before semantic (the latency of N450 occurs sooner than that of N400). This latency reverses for the ERPs in the written words. This could be compatible with a lexical "direct" strategy for reading in Spanish.

However, in children with reading problems and a low IQ (garden-variety poor readers) we found subtle linguistic ERPs differences which distinguish lexical ("direct") from non-lexical ("phonological") readers, and which could reflects the kind of strategy the reader takes in each case. Semantic access occurred before phonological, in auditory mode as well as visual, in garden-variety poor reader children who presented a lexical profile: their ERPs indexing phonological access were impaired (no N450 for printed words was found and later onset for N450 to spoken words). On the other hand, in children with a non-lexical pattern, phonological access occurred sooner (N450 appeared before N400 in auditory and visual mode; see Figure 3). On this line, we can see assimetric electrophysiological distribution for lexical and non-lexical garden-variety subgroups in Figure 4.

In the case of dyslexics with a high IQ we found an electrophysiological profile similar to the good readers, what also suggests a lexical reading strategy.

In conclusion, the study of linguistic ERPs yields valuable information which complements the neurophysiological exploration of reading.

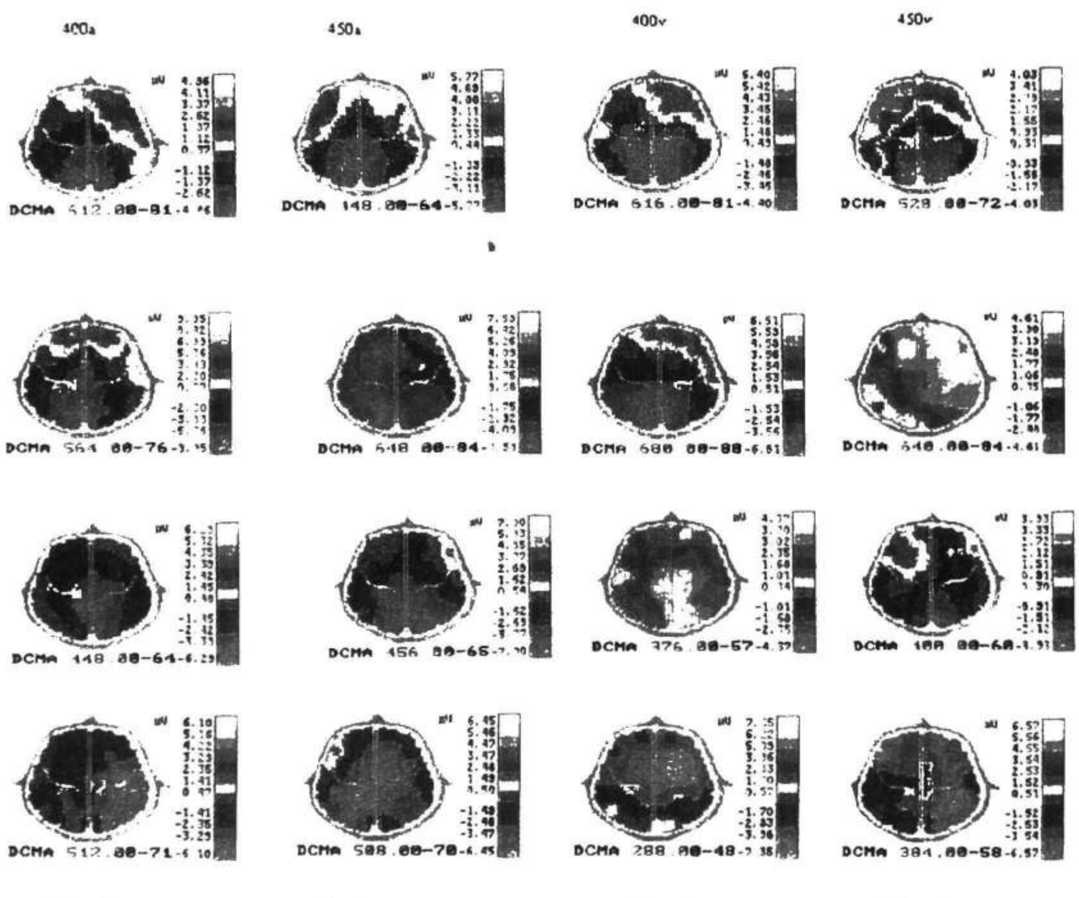

Figure 4: Electrical distribution activity mapping for each group (top to down: good readers, lexical garden-variety, non-lexical garden variety, and dyslexics), showing ERPs N400 and N450 significative hemispheric differences between lexical, and non-lexical sub-groups of garden-variety poor readers.

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