CHRONOLOGY OF READING PROCESSES

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Introduction

Written language is a widespread means of communication: therefore, most of the daily information are usually acquired through reading. Cerebral reading processes are based on the interaction among several components as visual/auditory perceptive systems, verbal-motor coordination, attention, phonological analysis skills, memory and feedback processes. The activation timing of these sensorial and cognitive components is crucial for an efficacious and efficient fulfillment of reading functions. Event-related potentials represent the cerebral electrical responses with a good temporal resolution: therefore, they can be employed to study the temporal relationships among the several processes involved in reading.

AIM

To investigate the time course of normal cerebral reading processes

Reading-related potentials (RRPs) were recorded during four different reading tasks

Experimental protocol

Subjects: 32 healthy children (23 males, mean age 9.56 ± 0.67 yrs).

Stimuli: 21 Italian alphabetic capital and small letters and non-alphabetic symbols (such as /, *,], %) visually presented by a vacuum fluorescent display. A minimum of 4 sets of stimuli was presented in the same random order for all subjects. Stimuli appeared on the screen when a technician or the examined subject himself pressed a button.

Reading tasks:

Letter presentation (LPR)	***passive*** observation of letters
Symbol presentation (SPR)	***passive*** observation of symbols
Externally-paced letter recognition (LRE)	***active*** reading aloud of ext.-paced letters
Self-paced letter recognition (LRS)	***active*** reading aloud of self-paced letters

Recordings: Each trial lasted 4 s, 2 s pre- and 2 s post-stimulus.
EEG was recorded from 10 standard 10-20 scalp sites (Fz, Cz, Pz, Oz, C4', C3', T4, T3, P4, P3) referred to linked mastoids. EOG was bipolarly recorded using two electrodes diagonally placed above and below the right eye. EEG and EOG signals were sampled at 250 Hz.
Lip movements (LIPS) were bipolarly recorded by two electrodes placed on the superior and inferior *orbicularis oris* muscles. A microphone was used to record subjects' voices.
EMG activity of the forearm flexor muscles (ARM) was recorded during the self-paced task for monitoring button presses of the subjects being examined.
ECG and pneumogram were also recorded.

Data analysis

Ocular artifacts superimposed to EEG were reduced from single trials applying a PCA method [1]. Averaged RRPs were computed for each task and subject. Grand averages of RRPs were obtained for each task. The latency and amplitude of the most relevant RRP components were measured by a skilled technician.

Results

Reading a letter surely requires to visually perceive the stimulus, then to process visual information for finding the corresponding phoneme and finally to set and execute articulation movements. During reading aloud, LIPS allows to identify the temporal window in which verbal production occurs. During self-paced tasks, ARM shows when the act of reading voluntary begins. Therefore, RRPs can be temporally divided into several periods, each related to a different stage of the reading processes (see Figure 1). We assume that a similar configuration is applicable even to RRPs recorded during passive silent reading.

The **pre-motor period** characterizes self-paced tasks and occurs before EMG onset of ARM. The component called Bereitschaftspotential (BP) is recorded [2]: this potential slowly increases in amplitude for about 500 ms and is mainly recorded in frontal, central and pre-central regions. It is can considered as an index of the subject's intention to begin reading.

The **pre-lexical period** corresponds to the appearance of the stimulus on the screen and it covers ARM phasic activity before the EMG onset of LIPS. The components P0, N1, P1 are recorded: they represent the first stages of the visual information processing and are mostly present on the occipital and parietal areas. During self-paced tasks, Motor Cortex Potential (MCP) is also measured: it is related to the sensorial proprioceptive information arriving in the pre-central cortex after movement execution for button pressing [3].

The **lexical period** occurs during the rising side of LIPS before the maximum value, i.e. during reading aloud. The components N2, P2, N3, P4, N4, Narea are mainly measured in the frontal, central and pre-central regions: they probably reflect the mechanisms for verbal-motor production control

The **post-lexical period** overlap with the dropping side of LIPS when the subject has already finished reading. The components P600, P600area, Larea are recorded especially in the parietal and occipital areas. These components can be related to memory and feedback mechanisms usually employed for learning to read.

Attention processes are surely spread in the whole RRPs: their role is evident during the pre-lexical and lexical periods through an increase of P1, P2 and Narea amplitude and a reduction of P2 latency.

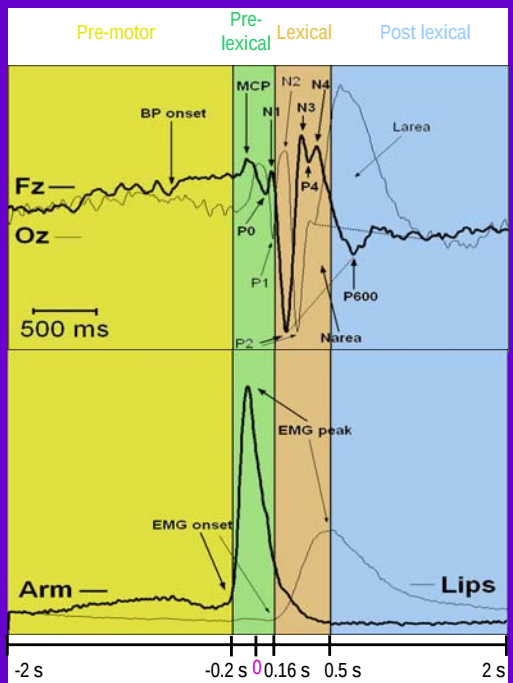

Figure 1:Chronology of RRP components

Latency and amplitude of the RRP components in the four periods varied according to task condition, as shown in tables 1, 2 and 3.

	AMPLITUDE (μV)						LATENCY (ms)				
	Fz	C4	C3	Pz	P4	T4	Cz	C3	Pz	P4	Oz
P1						–	P0	+			
N2							N4			–	–
P2				–	–		P600		–	–	–	–
N3	–										
P4			–	–							

Table 1: Amplitude and latency significant changes passing from LPR to SPR condition.

	AMPLITUDE (μV)								LATENCY (ms)		
	Fz	Cz	C3	Pz	P4	P3	Oz	T4	T3	Pz	C3	T3
N2								+		N2		–
P2	+		+	+	+	+	+	+		P2	+		
N3	+		+					+	+	P600	–	–	
P4		+		+	+	+						

Table 2: Amplitude and latency significant changes passing from LPR to LRE condition.

	AMPLITUDE (μV)										LATENCY (ms)			
	Fz	Cz	C4	C3	Pz	P4	P3	Oz	T4	T3	Pz	C3	T4	T3
P1		+	+		+	+	+		+		N2				+
N2									–		P2		–		
P2					+	+	+				N3			+	
N3			+	+	+	+	+	+	+		P600	+	+		
P4		–		–	–		–			–					
N4	–							+							

Table 3: Amplitude and latency significant changes passing from LRE to LRS condition.

Discussion

Comparison between passive presentation of letters and symbols. In SPR, the amplitude of pre-lexical and lexical components was reduced in most cerebral areas and the latency of lexical and post lexical components was also reduced in pre-central, parietal and occipital regions. These results suggest that less cognitive resources are employed for processing non-alphabetic symbols in comparison with visual processing of letters (4).

Comparison between passive presentation of letters and active recognition of externally-paced letters. Reading aloud produces a significant increase of amplitude of the lexical components in all the recorded areas. Furthermore, latency of P600 component in parietal and left-temporal regions and of N2 component in left pre-central region are reduced in LRE. These observations probably depend on articulation movements and on increased attention due to active participation to the task (5).

Comparison between reading aloud of externally-paced and self-paced letters. Voluntary reading determines a further increase of amplitude of pre-lexical and lexical components in all the cerebral regions; only P4 amplitude is reduced. Furthermore, the latency of lexical and post-lexical components is increased in parietal, left pre-central and temporal areas. These morphological differences can be assigned to the involvement of preparation and volitional processes.

These physiological evidences can be used in understanding the lack of acquisition of reading skills in different pathological conditions, as developmental dyslexia.

References

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