

# Differences in Saccadic Eye Movement-Related Potentials Under Regular and Irregular Intervals of Visual Stimulation

F. JAGLA, V. ZIKMUND, J. KUNDRÁT

*Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovak Republic*

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## Summary

The saccadic eye movement-related potentials (SEMRPs) were recorded over various brain areas in a group of righthanders while they performed saccades to visual stimuli appearing either at regular or at irregular time intervals. The premotion positivity, motion execution component and lambda responses were of shorter latencies and lower amplitudes over the parietal areas as compared to the occipital ones. This finding did not depend on the regularity of intervals. With regular intervals, the positive wave starting before and peaking at the end of a saccade was found over the frontal eye fields. With irregular intervals, the premotion negativity was registered over the motor and frontal cortices. With saccades at regular intervals, the oculomotor components in the SEMRPs were less pronounced as compared to the irregular ones. These results are in accordance with the presumption that visual stimuli, appearing at irregular intervals, require higher attention and readiness to the oculomotor reaction, respectively, and also with the supposed role of the right hemisphere of righthanders in processing visual information.

## Key words

Evoked potentials – Saccadic eye movements – Regular saccades – Irregular saccades

## Introduction

The saccadic eye movements are fast jumping movements subserving the reaching and fixation by the eyes of objects attracting the attention of man and other foveate animals. The programming of visually triggered saccades depends on complex sensory, motor, intentional and cognitive processes.

The visual-oculomotor integrations taking part in the programming of the saccadic eye movements have been studied by means of evoked potentials time-locked to the saccadic eye movements (SEMRPs) and their particular components, respectively (Becker *et al.* 1972, Gaarder *et al.* 1964, Kurtzberg and Vaughan 1973, Rémond *et al.* 1965). As the oculomotor components of the SEMRPs, the premotion negativity, premotion positivity, saccadic motion execution component, and, as the electrophysiological correlate of processing visual information, the lambda response have been described. The premotion negativity represents a negative antecedent slow potential that may be recorded before a variety of motor acts, e.g.

Bereitschaftspotential (Kornhuber and Deecke 1964). The other above mentioned components are specific potential changes reflecting the visual-oculomotor integrations. The premotion positivity (starting 100–200 ms before onset of the saccade) is assumed to represent the correlate of formulating the motor plan for saccadic eye movement execution (Armington 1978). The saccadic motion execution component reflects the proper execution of the saccadic motion of the eyes. The lambda response (a pronounced positivity 120–140 ms after onset of the saccade) reflects the input of new visual information to the cortex (for review see Marton *et al.* 1983).

In our previous study (Jagla and Zikmund 1991) the characteristics of the SEMRPs were described over the frontal, central, parietal and occipital areas when subjects performed the horizontal saccadic eye movements elicited by two fixational targets separated by 10 deg. The targets were switched on and off at regular 2 s intervals alternatively, 50 times

repeatedly. Such a stereotyped presentation of visual stimuli allows the subject to predict the time appearance and location of the visual stimulus and enables him to perform the saccadic eye movements rather automatically, leading thus to a gradual decrease of attention on the visual task.

In the present report, the latencies and amplitudes of the above components in the SEMRPs were compared when the horizontal saccades elicited either at regular or at irregular time intervals between the two consecutive visual targets.

## Material and Methods

### Apparatus and procedure

The examinations were performed in a darkened room, subjects sitting in a comfortable arm-chair with their heads moderately fixed by a headrest. A panoramic projection screen (120 x 20 deg) was placed at a distance of 1 m from the subjects eyes. A grating from black and white vertical stripes (1:1 ratio, 5 deg width) served as a visual background.

The saccadic eye movements were elicited by the white circular targets of 0.5 deg in diameter which were switched on and off at the centre of the visual field and 10 deg to the right and to the left under two experimental conditions: (1) at regular 2 s intervals and (2) irregularly, at 2 to 5 s intervals between the two consecutive presentations of stimuli. The differences concerning the direction of saccades to the right and to the left were not taken into account, as they were described previously (Jagla and Zikmund 1994).

The horizontal saccadic eye movements were recorded electrooculographically (EOG - t.c. 1.5 s, filter 15 Hz) with the electrodes (DANTEC 13L71) fixed near the outer canthi of the eyes.

Similar electrodes, affixed over the areas 17,5-7,4 and 8 of the right and left hemisphere were used to record the EEG (t.c. 0.3 s, filter 30 Hz). The grounding electrode was placed on the vertex and the joined process mastoidei were used as the reference.

### Data collection and analysis

The EOG and EEG were continually recorded on the EEG apparatus BIOSCRIPT 2100 and were stored on a frequency-modulated taperecorder. The onset of saccades served as a trigger for the averaging procedure performed by a laboratory microcomputer. A total number of 50 sweeps was averaged from each of the recording electrodes under both experimental conditions. The averaged segments of EEG activity started 500 ms before the onset of the saccadic eye movements and the whole analyzed time covered 2 s. The latencies and amplitudes of the analyzed SEMRP components (the sensitivity of the system was 0.5 ms and 0.01  $\mu$ V, respectively) were statistically evaluated by means of the paired t-test. The grand averages from

both the hemispheres were written out on a X-Y plotter.

### Subjects

Ten undergraduates, pronounced righthanders with normal vision (6 women and 4 men, mean age 21.2 years), served as subjects. They were selected on the basis of scores in tests proposed by Černáček (1964), in the Orientation in Lateral Preference Scale (Kováč 1973) as well as according to two performational tests (30 s dotting and tracing).

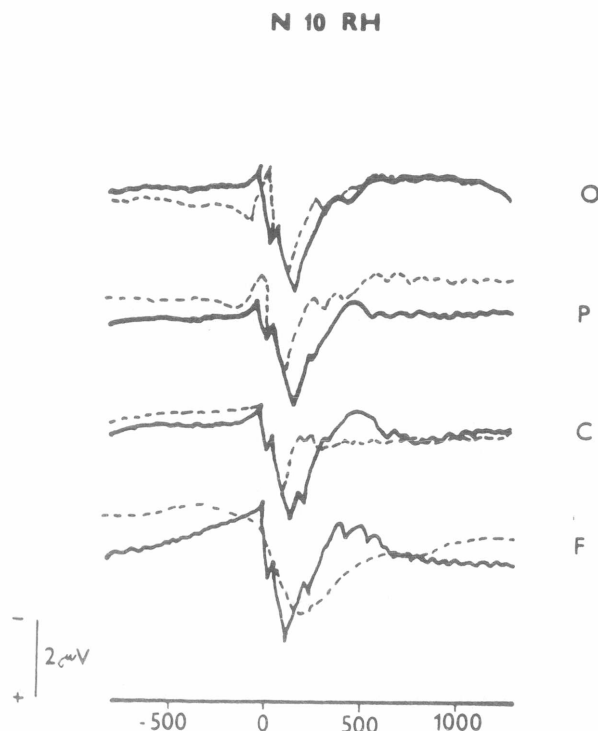


Fig. 1

The saccadic eye movement related potentials (overall averages) from both hemispheres over the occipital (O), parietal (P), motor (C) and frontal (F) areas under visual stimulation at regular (broken lines) and at irregular intervals (solid lines). Zero on the time axis indicates the onset of a saccade.

## Results

The following main differences in the latencies and amplitudes of premotion negativity, premotion positivity, motion execution component and lambda response were found over the particular cerebral areas when the saccadic eye movement-related potentials were registered under regular and irregular time intervals between the two consecutive visual stimuli (Tables 1 and 2).

**Table 1**  
Latencies of premotion negativity (ms) registered under irregular time intervals

	Right area	Left area
Motor cortices (latency)	380±18.0***	540±20.0
Frontal eye fields (latency)	480±20.0***	825±23.0

Means ± S.D., (\*\*\*)  $p < 0.01$

The positive wave with slowly increasing and decreasing positivity and with the amplitude of about  $4.5 \pm 0.3 \mu V$  was found with regular refixations.

**Table 2**  
Latencies and amplitudes of premotion positivity, motion execution component and lambda response registered under regular and irregular time intervals

Premotion positivity			
	Amplitudes ( $\mu V$ )		
	ITI		RTI
Occipital areas	2.6±0.12	*	2.4±0.10
Parietal areas	2.1±0.11	*	1.9±0.09
	Latencies (ms)		
Occipital areas	195±11.5	*	170±10.5
Parietal areas	185±14.0	*	160±12.5
Motion execution component			
	Amplitudes ( $\mu V$ )		
	ITI		RTI
Occipital areas	1.6±0.08	*	1.3±0.07
Parietal areas	1.4±0.07	*	1.2±0.09
Lambda response			
	Amplitudes ( $\mu V$ )		
	ITI		RTI
Occipital areas	8.2±0.05	*	7.2±0.04
Parietal areas	8.8±0.08	**	7.3±0.07
Motor cortices	9.2±0.11	**	7.6±0.13
	Latencies (ms)		
Occipital areas	125±10.5	*	110±9.50
Parietal areas	120±12.0	***	103±10.5
Motor cortices	128±9.50	***	110±8.50

RTI and ITI, regular and irregular time intervals.  
Means ± S.D.; (\*  $p < 0.05$ ; \*\*  $p < 0.02$ ; \*\*\*  $p < 0.01$ )

Fig. 1 shows the grand averages from both the hemispheres at regular and irregular intervals between two consecutive visual stimuli.

Discussion

The mechanisms of visual-oculomotor integration still remain largely unknown. Single unit studies concerning the brain areas which take part in processing visual information offer some insight into the neuronal circuitry underlying the integration of the visual and oculomotor components of visual perception. The occipito-parietal connections have been found to serve the processing of spatial location of visual objects in primates as well as in human beings (Damasio *et al.* 1982, Ungerleider and Mishkin 1982). The shorter latencies and lower amplitudes of premotion positivity and the lambda response over the parietal areas as compared to the occipital ones point to the higher readiness of the parietal areas to trigger the eye movements towards new visual stimuli. This assumption is supported by the findings of Lynch *et al.* (1977) that the posterior parietal cortex contains neurones discharging before the onset of a saccade.

Sava *et al.* (1988) ascribed the dominant role for the control of oculomotor activity to the right hemisphere of righthanders. Results presented in this work as well as in our previous study (Jagla and Zikmund 1989) point to the same side differences and support the data concerning the more significant participation of the right hemisphere of righthanders in primary encoding of basic space-shape characteristics of visual stimuli (Kimura 1966, Milner 1971).

The frontal eye field may be regarded as a constituent sector of the motor map specialized for the eyes (Schlag and Schlag-Rey 1992). We registered a strong positive potential starting before and peaking at the end of each saccade with the saccades performed by subjects at regular intervals, similarly as those described by Brooks-Eidelberg and Adler (1992). These authors expressed the view that they may be related to the discharges of cortical neurones that signalize the initiation of saccadic movements. When the subjects performed saccadic refixations with stimuli at irregular intervals, the SEMRPs over the frontal areas resembled those recorded over the posterior areas of the brain. However, the marked difference is caused by the premotion negativity in the SEMRPs with irregular saccades. This negativity has been ascribed to volitional activation (Kurtzberg and Vaughan 1982). It may be supposed that this activation and/or visual attention is higher when the subject has to fixate the target appearing at irregular intervals.

These results suggest that, with the regularly appearing visual stimuli, the components of programming the eye movements in the SEMRPs become less expressed because of a certain

automatization of the oculomotor reaction. When a subject cannot anticipate the appearance of a visual stimulus, however, the readiness to react with a saccade must be maintained at the same level for the whole period of visual stimulation, which is reflected in the

more pronounced preparatory components for eye movements during SEMRPs.

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F. Jagla, M.D., Ph.D., Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Sienkiewiczova 1, 813 71 Bratislava, Slovak Republic.