DEPENDENCE OF PRESACCADIC CORTICAL POTENTIALS ON THE PREDICTABILITY OF STIMULUS

Presakkadik Kortikal Potansiyellerin Uyaran Tahmin Edilebilirlik Bağımlılığı

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Abstract

Purpose: *The goal of the present study was to assess the effect of stimuli predictability on presaccadic cortical potentials.*

Material and Methods: *In the present study, two scalp potentials recorded prior to saccades in relation to visual targets (the presaccadic negativity [PSN] and the presaccadic positivity [PSP]) were studied in ten healthy subjects, performing visually guided horizontal saccades in darkness. Presaccadic potetials from Fz, Cz electrode sites and eye movements from external canthi were recorded as simultaneously. Two interstimulus intervals (ISI) (regular 6 sec, and irregular 3 – 9sec) were used to exemine the differences in presaccadic activity under different conditions (predictable [P] vs unpredictable [UP] conditions). The technique of back-averaging from the onset of saccade was applied and separate wave forms were obtained for both conditions in each subject.*

Results: *A slow negative shift began approximately 1200 msec before eye movement in UP condition, and 950 msec in P condition. The difference was statistically significant. The integral over presaccadic negativity was significantly greater for UP condition at the Fz and Cz location than in P condition. There was no significant differences between UP and P conditions when compared the onset time or amplitude of the PSP.*

Conclusion: *These results support the hypothesis that presaccadic negativity is related to non-specific processes such as attention, arousal, motivation or volitional effort, rather than specific processes. However, our findings do not exclude the role of presaccadic programming, reflecting activity of the cotical eye fields on presaccadic cortical activity.*

Key Words: *Contingent Negative Variation; Eye movements, saccadic.*

Özet

Amaç: *Sunulan çalışmanın amacı uyarının önceden tahmin edilebilirliğinin presakkadik kortikal potansiyeller üzerine etkisini araştırmaktır.*

Yöntemler ve Metod: *Sunulan çalışmada, karanlık bir ortamda horizontal sakkadik göz hareketleri yapan 10 sağlıklı gönüllüde, görsel hedeflerle ilişkili olan ve sakkadik göz hareketlerinden önce oluşan iki saçlı deri potansiyeli (presakkadik negativite, PSN ve presakkadik pozitivite, PSP) çalışıldı. Göz hareketleri dış kantüslerden kaydedilirken, bununla eş zamanlı olarak, presakkadik potansiyel Fz ve Cz yerleşimlerinden kaydedildi. Düzenli (6 sn) ve düzensiz (3-9 sn) olmak üzere iki uyarı arası zaman örneği, farklı koşullar (tahmin edilebilir ve tahmin edilemez koşullar) altında presakkadik aktivitedeki farklılığı araştırmak için kullanıldı. Her bir gönüllüden elde edilen süpürümler, sakkadın başlangıcından geriye doğru ortalama tekniği kullanılarak analiz edildi.*

Bulgular: *Tahmin edilemez koşulda sakkadik göz hareketinden yaklaşık 1200 ms önce tahmin edilebilir koşulda ise 950 ms önce başlayan yavaş bir negatif kayma tespit edildi. İki koşul arasındaki farkın anlamlı olduğu bulundu. Presakkadik negativitenin integral değeri, tahmin edilemez koşulda tahmin edilebilir koşula göre daha büyüktü. Presakkadik pozitivif dalganın başlama zamanı ve amplitüdü değerlendirildiğinde iki koşul arasında anlamlı bir fark bulunmadı.*

Sonuç: *Çalışmamızdan elde edilen bulgular, presakkadik negatif değişimin spesifik süreçlerden çok dikkat, uyanıklık, motivasyon veya iradeli davranış gibi spesifik olmayan süreçlerle ilgili olduğu hipotezini desteklemektedir. Bununla birlikte, bu bulguların presakkadik kortikal etkinlik üzerine presakkadik programlamanın ve kortikal görme alanlarının etkisini dışlamayacağını düşünmekteyiz.*

Anahtar kelimeler: *Rastlantısal Negatif Kayma; Göz hareketleri, sakkadik.*

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Introduction

The role of the cerebral cortex in the preperation and generation of saccadic eye movement has been demonstrated in animal experiments. In the monkey five different cortical areas have been identified in this respect, three in the frontal cortex and two in the posterior parietal cortex (1). The origin and the functional significance of these presaccadic potentials in humans are still a matter of discussion, and have led to the investigation of presaccadic EEG potentials.

In humans, changes of presaccadic cortical activity when performing visually-guided, memory-guided or self placed saccades along vertical, horizontal and oblique meridians in total darkness have been recorded since the 1970's. Presaccadic scalp potentials consist of 3 components: a slow negative shift (presaccadic negativity, PSN), a positive antecedent potential (presaccadic positivity, PSP) (2) and a spike potential (SP) (3). The first and second of these, PSN and PSP, are the subject of this study.

The first wave, PSN, is a negative ramp-like potential. It is found to start approximately 1 sec. or earlier prior to eye movement onset (3,4,5). It is similar to the readiness potential preceding voluntary movements of the extremities (7). Its amplitude is maximum over the frontal regions and vertex (4,5,6,8,9) and greater at the electrode sides counterlateral to the direction of self-paced saccades (5,9) or anticipatory saccades (8). Interpretations of this presaccadic negativity vary between activity of ocular motor areas such as the frontal eye field (4) or the supplementary motor area (6), and primarily non-movement-specific activity related to psychological process such as attention, arousal, preparedness to move (7) or the decision to act (3). Since significant lateralization effect have been found only in connection with saccades leading to a preparatory activation of cortical motor areas, more recent investigations have led to the conclusion that the PSN is a readiness potential (9).

The PSN turns to positivity at about 300 msec prior to the onset of saccade, namely the second wave, PSP. It is found to start approximately 30-300 msec prior to eye movement onset (3,4,10). Although the PSP has been thought mainly to reflect the activity of parietal visuomotor region (4,10), since this potential is bilaterally symmetrical (4,6), it is difficult to reconcile with the idea of a specific presaccadic function. Furthermore, distinction of the PSP from negativity prior to PSP is complicated (6).

The origin of presaccadic cortical activity can be attributed to one of these two causes, or both. Some authors consider the PSN to be specifically related to saccade programming (4,6). Others hypothesize that the PSN mainly represents cortical acitivity related to non-specific processes, such as attention or arousal (7,8,11). Klosterman et al presented evidence that PSN can be attributed to both causes (9). In the present study, we believe that the change in ISI would help to distinguish between unspecific effect related to the subjects' attention (supposed to be higher in irregular ISI than in regular ISI) and specific effects related to the cortical preparation of saccades (considered to be similar under both conditions).

Material and Methods

Subjects and procedures: Ten healthy, right handed (4 males, 6 females), aged between 25 – 54 years (mean: 35.3 ± 2.58 SEM) were included in this study. Vision was normal or adequately corrected for refraction. The subjects reclined comfortably in a chair, with the head immobilized in a head-holder, 2m in front of a Light Emitting Diode (LED) panel including fixation points, one of which was positioned in the centre and the others at eccentricity of 5 and 10 degrees. The angle between the two points was kept to a minimum in order to maintain low electrooculography (EOG) voltage excursion. Subjects were instructed to fixate the central point, then to look at the LED on the panel whenever it was lit. In the P condition the subjects were instructed that ISI was 6 sec and regular; in the UP condition ISI varied 3 – 9 sec. Both experimental conditions consisted of 20 rightward and 20 leftward saccadic eye movements and were performed in altering order, separated by breaks of a few minutes.

Recording: Scalp electrical activity was recorded from Ag-AgCl electrodes placed on Fz and Cz according to the international 10-20 system. The horizontal EOG was recorded with electrodes placed adjacent to the lateral canthi. Both EEG electrodes were referred to linked left ear lobe, and the EOG electrodes to forehead. The right ear lobe was used as ground. EEG signals were amplified using Nihon Kohden bioelectric amplifier AB621-G with a time constant 2 sec and low-pass filter of 100 Hz. EOG signals were amplified using Nihon Kohden ENG amplifier AN601-G with a time constant 3 sec and low-pass filter of 20 Hz. The output of amplifiers was digitalized on line at 1000 Hz sampling rate and stored on hard disc for off-line analysis.

Data analysis: During off-line analyse, the recording epochs of each trial were displayed on the computer monitor. Trials with saccades in the wrong direction or artifact were excluded from analyse, as well as trials with saccade reaction time (SRT) >450 msec. The selected epochs were stored in different buffers separately for two different saccade directions and two different conditions (predictable – unpredictable). Saccade onset was defined as time zero. The averages of epochs were triggered on saccade onset, and were baseline-corrected to the average voltage of an interval between –1680 and +20 msec.

Statistics: From the averaged data, the onset time, the maximum PSN amplitude, the time in which amplitude is at maximum, and the integral of the potential shift above or under baseline as a global measure of presaccadic activity of both PSN and PSP were obtained separately for each subject. The statistical evaluation of these parameters was examined by the Student’s t-test.

RESULTS

In the predictable condition an average number of 20 artifact-free saccades and in the unpredictable condition an average number of 18 artifact-free saccades were obtained for each subject. With the illuminations used in this study for background, fixation points and target, the SRT range of predictable saccades was 200±23.4 msec and that of unpredictable saccades was 203±21.1 msec (t:0.97,p>0.05). The mean velocity values were 435±51.3 degree/sec and 430±57.3 degree/sec for P and UP conditions, respectively (t:1.13,p>0.05). No statistical differences were found between presaccadic negativities preceding leftward and rightward saccades. Therefore, the data of right and left saccades were pooled.

A distinct PSN was observed in both conditions in all subjects at Fz and Cz electrode sites. The grand average of 10 subjects is shown in Figure 1. The grand average showed PSN onset as approximately 950 – 1200 msec prior to saccade onset for both conditions. Before PSN onset, there was an isoelectrical plateau of about 800 msec duration. Between the maximum PSN and the onset of saccade, a PSP was also recorded for all subjects.

The average potential amplitude of 100 msec interval, i.e., 50 data points at 2 msec intervals, were tested for the difference from zero (paired t test) separately for both electrodes under both conditions. A statistically significant difference of PSN amplitudes from baseline was found. Similar findings were also obtained from the analysis of PSP amplitudes.

Table 1 shows the mean values of the PSN and PSP time onset and SE of means. Statistical analysis results were also presented in Table 1. In unpredictable conditions, the PSN was found to begin earlier than in predictable condition. There was no difference between electrode sites when the PSN time onset was compared. For unpredictable condition, however, the PSN begun about 50 msec earlier in Fz than Cz. The PSP onset time in UP condition was not different from that of P condition statistically. Table 1 also shows integrals of presaccadic waveforms as a global measure of the PSN and PSP amplitudes. Amplitude values are presented as relative value to lower one. The PSN amplitude was larger in unpredictable condition than predictable condition. The integral over presaccadic positivity in UP condition was not statistically different from that of P condition. There was no difference between electrode sites when PSN or PSP amplitudes was compared. Figure 2 shows grand average curves calculating by subtracting to potential in UP condition from that in P condition for each subject. The figure indicates that the difference between potentials of UP and P conditions begins approximately at –1200 msec, is maintained during 700 msec, and decreases about 500 msec prior to saccade onset.

Table 1. The mean value and SEM of presaccadic negative and positive potential recorded at Cz and Fz electrode sites in 10 healthy subjects.

Wave	Fz				Cz			
	P	UP	t	p<	P	UP	t	p<
PSN time onset (msec)	946±76	1162±60	2.27	0.05	929±62	1205±87	2.64	0.03
PSP time onset (msec) ±SEM	124±12	129±12		ns	115±6	114±8		ns
PSN amplitude ±SEM	1.0±0.0	2.52±0.03	6.46	0.001	1.0±0.0	3.78±1.26	7.15	0.001
PSP amplitude ±SEM	1.0±0.0	1.20±0.22		ns	1.0±0.0	1.05±0.18		ns

In average PSN amplitude reached its maximum at Cz and Fz in both conditions: 1.72 and 1.69 ìV at –307 and –259 msec in predictable condition and 1.66 and 1.70 ìV at –266 and -219 msec in unpredictable condition. There was no difference between conditions or electrode site when the time in which amplitude is maximum and maximum amplitude in PSN were compared.

Discussion

The data obtained in this study clearly demonstrated that there was presaccadic cortical activity prior to saccade onset. Since we recorded isoelectric plateau of about 600 msec duration, we concluded that the activity is related to delayed EOG voltage decay. In the present study subjects performed visually guided saccades. The onset of PSN was determined to be approximately 950 and 1200 msec prior to the onset of saccade (P and UP conditions, respectively). In some studies the authors recorded a PSN with duration of approximately 1 sec (3,6,8). However in other studies it had not been possible to determine the exact onset of PSN (4,11). Klosterman et al found that the PSN started approximately 3 sec prior to the onset of the saccade (9). Similar findings were also presented for duration of the readiness potential: the time onset of readiness potential varied 0.5 sec (12) and 3 sec prior to the beginning of the movement (13). We believe that apart from technical differences, the instructions given to subjects can also affect the onset of PSN.

In the present study, amplitude and time onset of PSN were different in P and UP conditions, as is shown in Figure 1 and Figure 2. Since there was no differece between UP and P conditions when the saccade metrics were compared, this difference was not caused by subjects' oculomotor performance. We supposed that, during UP condition, the subjects who participated in our study had a higher arousal level and paid much more attention to visual target, as they did not know when LED was going to go on. We believe, higher level of such psychophysiological factor can be result in larger and earlier PSN. This finding is in line with some other findings in the literature and the hypothesis of Becker et al who originally proposed that PSN before saccade is influenced by the pschophysiological processes (3). Klosterman et al found that PSN duration decreases in the course of recording session and interpreted the differences between the early and later blocks of trials as cortical activity related to test persons' attention and motivation (9). In the present study larger and easier PSN in UP condition cannot be due to fatigue or decreased motivation since performance or the oculomotor task remained unchanged between the conditions. Evdokimidis et al reported greater PSN in naive subjects than trained ones (8). In another study by Evdokimidis et al , it was found that when a visually guided saccade task is running, the presaccadic potentials obtained in the initial period of the task differs from those obtained later (14). Thickbroom and Mastaglia found that presaccadic potentials' slope and duration were influenced by the predictability of the triggering stimulus, and that the slope was greater and the duration shorter with predictable than with unpredictable stimuli. They concluded that, when the precise timing of the cueing stimulus was not known by the subjects, a negative potential still developed but then plateau until the arrival stimulus and execution of the movement (10). An analogous correlation between readiness potential and non-specific psychophysiological factors has already been reported for limb movement-related potentials (15,16). With regard to the maximum in PSN amplitude and time onset and integral over PS, UP and P conditions did not differ, indicating that around the point of the maximum, and the time integral between this point and saccade onset the activity of all cortical areas involved depends less on psychophysiological factors.

In the present study, approximately 100 msec prior to saccade onset, PSN was followed by a positivity, as was similarly noted for the readiness potential preceding limb movement (16,17). In literature it was reported to start about 30 – 300 msec prior to saccade onset (3,10,4). PSP, in the present study, showed no differences between UP and P conditions. Because the premotor positivity is considered as the elaboration of the "motor plan" (8,16), our finding indicate that the elaboration of motor plan is not influenced by the reproducibility of stimuli. In contrast to our findings, Thickbroom and Mastaglia reported the slope to be greater and the duration shorter with predictable than unpredictable stimuli (10). We could not explain this discordance.

In conclusion, presaccadic potentials probably represent cortical activity related to psychophysiological processes, overlapping activity of cortical areas related to preparatory processes of saccadic eye movement. In the first period of the presaccadic potentials (negative wave) psychophysiological factors are dominant, however in the later phase, motor planning of saccadic eye movement is.

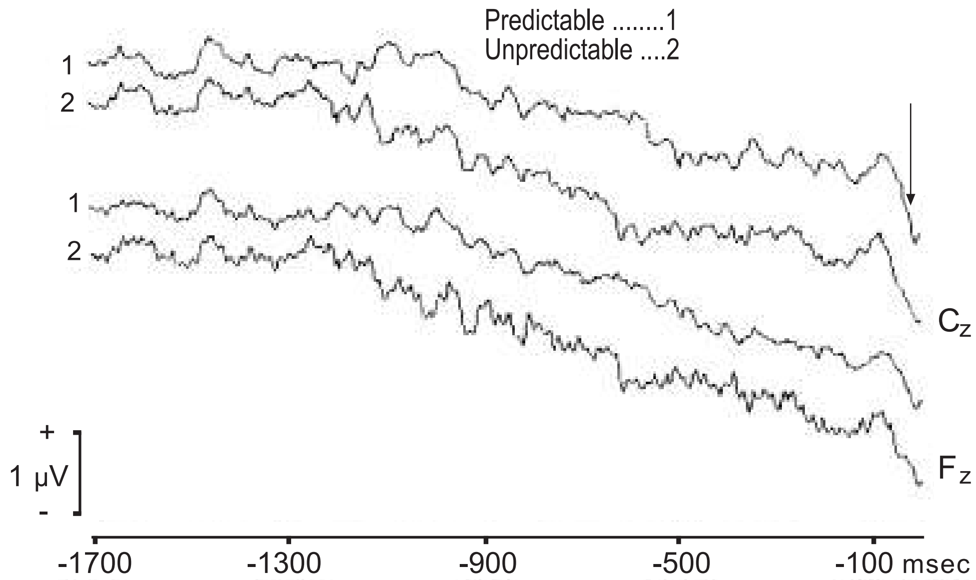

Figure 1. The grand average of presaccadic potential recorded at Fz and Cz positions in response to visual stimulus with regular (predictable) and irregular (unpredictable) interstimulus interval (ISI) in 10 healthy subjects. The arrow indicates the onset of saccadic eye movement. It is noted that presaccadic negativity started earlier in irregular ISI condition.

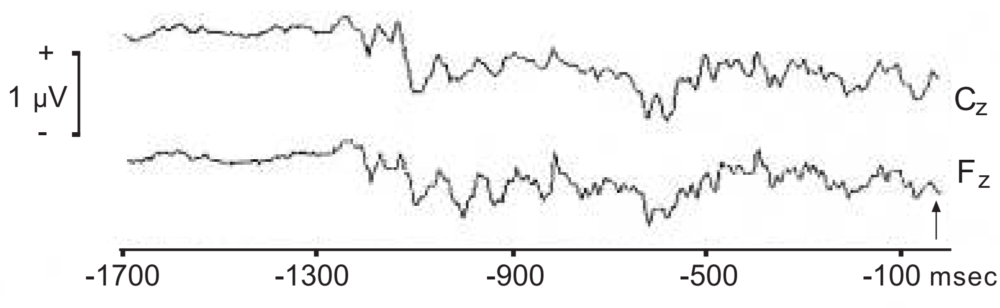

Figure 2. Grand average curves calculated by substracting to potential in unpredictable (UP) condition from that in predictable (P) condition for each subject. It is noted that the differance between potentials of UP and P conditions begins approximately at –1200 msec, maintains during 700 msec, and decreases about 500 msec prior to saccade onset.

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