

## Electrographic Correlates of Predictions of the Time Course of Events

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Correlates of predictive activity associated with observation of patterns in sequences of events were studied. Predictive cues consisted of fixed sequences of three stimuli preceding the appearance of a target (control) stimulus, to which the subject had to respond by pressing a computer mouse button as quickly as possible. Reaction times were analyzed for control stimuli, along with the characteristics (amplitude, duration) of contingent negative variation (CNV) in EEG fragments preceding the predictive cue stimuli and the control stimulus. Increases in CNV amplitude were demonstrated in the series of predictive stimuli preceding the appearance of the target stimulus, and this correlated positively with target stimulus reaction times.

**Keywords:** EEG, predictive activity, contingent negative variation.

Adaptive behavior in humans is based on the ability to foresee events on the basis of past experience, which is reflected in the subjective model of a situation. This ability is based on a prediction mechanism. According to ideas formulated within the concept of the predicting brain, people constructing such models generally work not on the basis of the occurrence frequency of real events (which because of the small number of observations often cannot be determined confidently), but on the basis of confidence in their own judgment, or so-called Bayesian probability [Freeman, 2003; Yu and Dayan, 2005; Friston, 2009, 2010; Bubic et al., 2010; De Ridder et al., 2013, 2014]. A number of authors regard this mechanism as an alternative to the reflex strategy of behavior, providing flexibility [Brembs, 2011].

According to Hawkins, prediction is a basic function of the neocortex and is based on intellect [Hawkins and Blakeslee, 2007]. “Ensembles of predictive nerve cells,” discharging particularly in expectation of a sensory event, are seen in many brain structures. Even in conditions of indeterminacy, the brain responds to events and generates predictions. Formation of cerebral activity corresponding to the taking of a decision on selecting an action occurs before

the person is aware of the choice [Soon et al., 2013] and the appearance of predicted events induces less brain activity than unexpected or novel events [Alink et al., 2010; Vetter et al., 2014].

Predictive brain activity has been experimentally demonstrated at different levels of its organization [Zelano et al., 2005, 2011; Tanaka, 2007; Maldonato, 2014]. Some authors indicate the possibility that there are specific nerve centers directly responsible for predictive activity. Thus, for example, Zacks' group [Zacks et al., 2011], working on the basis of their own fMRI studies, assigned this role to the substantia nigra, whose function they linked with observation of periods of indeterminacy, requiring renewal of hypotheses relating to forthcoming events. Pally [2006] and Kononowicz [2015] identified a special role for the dopamine system of the midbrain (the mesencephalic dopamine system, MDS), which encodes prediction errors when unexpected events occur. Nonetheless, current results [Brunia, 1999; Liang and Wang, 2003; Babiloni et al., 2006; Pally, 2006; Hawkins and Blakeslee, 2007; Kononowicz, 2015; Machinskaya et al., 2015] indicate that prediction is linked with the functioning of a hierarchically organized system, whose key elements are the frontal and parietal areas of the neocortex.

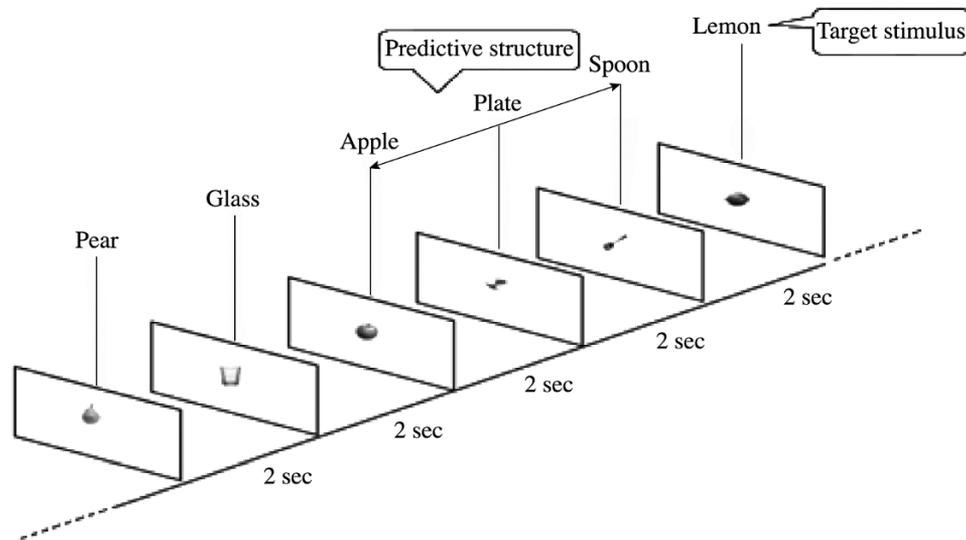


Fig. 1. Diagram showing a fragment of the stimulus sequence. The sequence of stimuli (apple-plate-spoon) used as the predictive cue is shown, along with the control stimulus (lemon).

Among the electrographic correlates of the predictive activity of brain structures, so-called contingent negative variation (CNV) is of particular interest. Many investigations have shown that CNV occurs in activity requiring responses to stimuli depending on the context of the information [Gomes and Flores, 2011; Tomita et al., 2012; Boehm et al., 2014; Pauletti et al., 2014; Rebekah et al., 2015; Kononowicz and Penney, 2016; Bubic et al., 2010; De Ridder et al., 2013, 2014]. In particular, this clearly forms during the interval between the warning signal and the relevant stimulus to which a response is required when both are present [Elbert et al., 1991; Cui et al., 2000; Gomez et al., 2003; Bender et al., 2004; Gomez et al., 2007; Fan et al., 2007; Jacobs et al., 2008; Flores et al., 2009; Gomes and Flores, 2011; Tomita et al., 2012; Boehm et al., 2014; Pauletti et al., 2014; Rebekah et al., 2015; Blakemore et al., 2015; Kononowicz and Penney, 2016]. The extent of CNV correlated with the probability of the appearance of the target stimulus. It was suggested that the main contribution to generating CNV came from activation of the frontal-parietal system [Gomez, 2007; Arjona and Gomez, 2014].

Reaction time (RT) is widely used for assessment of the effectiveness and interpretation of the results of predictive activity [Fan et al., 2007; Arjona and Gomez, 2014; Gomez and Flores, 2011]. Experimental studies have shown, in particular, that the higher the probability that a significant event (the stimulus) would occur, the shorter the reaction time to it [Feigenberg, 2008]. Shorter reaction times to highly likely stimuli are due to high levels of expectation (prediction) of its appearance and formation of a state of pretuning. The probability of the significant event may, apparently, be linked not only with the frequency with which it occurs, but also with the presence of some pattern in the series of events and the corresponding predictors,

which can be detected in the form of an insight, but also with the continuous process of “understanding” the situation, which is mediated via the formulation and subsequent testing of the corresponding hypotheses. All these points may provide grounds for prediction and have significant influences on the effectiveness of actions, particularly reaction times to target stimuli.

Thus, the phenomenon of CNV is currently linked with such mental phenomena as expectation, pretuning, prediction, and various others. The aim of the present work was to obtain more stringent evidence of an interaction between CNV and the mechanism of predicting sequences of events by assessing correlations between their extent with reaction time to the target stimulus.

**Methods. Subjects.** A total of 20 young adults (10 men, 10 women), year 2–5 students at the natural sciences faculties, Southern Federal University (mean age  $22.0 \pm 2.8$  years) took part in the studies. None had previously taken part in any psychophysiological investigations. In accordance with ethical standards approved by the Southern Federal University Ethics Committee, subjects gave written consent to take part in the electrophysiological investigations of ideomotor and perceptual activity with recording of the electroencephalogram.

**Stimuli and apparatus.** Stimuli were images of objects assigned to the categories “fruits” (apple, lemon, pear) and “tableware” (spoon, plate, glass). Stimulus material was presented on a 17" SunMaster-943n monitor screen. All stimuli were halftone images of these objects and had identical angular sizes ( $4^\circ \times 10^\circ$ ). Image brightness and gray tones were made uniform using Corel Photopaint X3 (“image convert to gray scale 16 bit” mode).

The experimental scenario was run in the Neostimulus environment from Neurobotix (Zelenograd). Stimuli were

TABLE 1. Results of Cluster Analysis of RT Values, K-Mean Method

Clusters	Mean reaction time	Number of cases	Proportion, %
1	199.1 ± 4.6	576	25.83
2	289.9 ± 5.8	620	26.72
3	380.1 ± 12.4	672	27.97
4	516.2 ± 5.9	304	13.10
5	725.75 ± 15.9	148	6.38

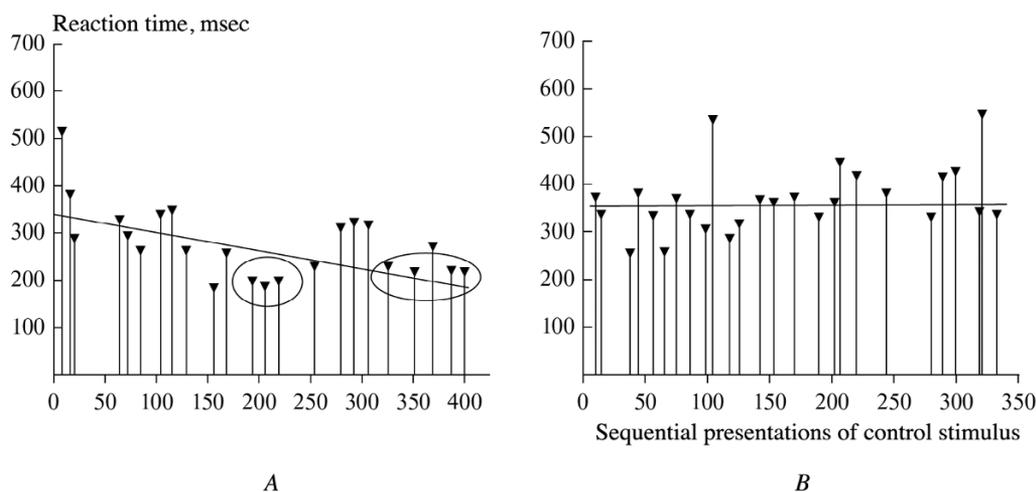


Fig. 2. Individual chronograms of two subjects with effective (A) and ineffective (B) prediction. The X axis shows sequential presentations of the control stimulus; the Y axis shows visuomotor reaction times. Red lines on plots show trends in RT values.

presented in random sequence and the duration of exposure of each was 300 msec, with interstimulus intervals of 2 sec. The state of expectation was formed by fixing the interstimulus interval at 2 sec. Subjects had to press a joystick button as quickly as possible when the control (target) image appeared, as specified in the instructions. The control image was presented only after a strictly defined sequence of three other images, namely, apple, plate, and spoon (Fig. 1), which was designated the “predictive cue” (PrC). Elements of PrC could be presented separately or in various combinations. In all other cases (except the PrC), stimuli were presented in random order.

The complete cycle consisted of 750 stimuli and lasted 30–40 min, including positioning of electrodes and presentation of instructions. This experimental duration provided stability in the subject’s functional state. Interviewing after each investigation to determine whether the subject identified the “predictive” sequence of stimuli served the same purpose.

**Analysis of individual and group chronograms.** Assessment of the effectiveness of predictive activity in the subjects was performed by analysis of individual chronograms (Fig. 2), which consisted of sequences of reaction

times (RT) to the target stimulus. Evidence for the occurrence of prediction consisted of reactions to the target stimulus with a time equal to or less than the mean time of the simple visuomotor reaction, which was determined before the main study individually for each participant. This was performed using 20 presentations to which the subject had to react as quickly as possible by pressing a joystick button and for which the mean value was computed. Effective prediction was when (for that particular subject) the individual chronograms showed series of RT which were equal to or shorter than the time for the simple visuomotor reaction (Fig. 2, A). This indicator was used to divide the subjects into two groups, with effective (EP) and noneffective (NP) prediction.

**EEG recording and analysis.** Throughout the study, a Neurovizor-BMM electroencephalogram (Neurobotix, Moscow, Russia) was used for continuous monopolar EEG recording from 14 leads (f3, f4, f7, f8, c3, c4, t3, t4, p3, p4, t5, t6, o1, and o2) using the international 10 × 20 system. The reference electrodes (combined reference) were located on the ear lobes. The sampling frequency for electrograms was 1000 Hz for each channel and the frequency filter band-pass was 0.5–100 Hz. In-phase interference was suppressed

using a 50-Hz rejection filter. Intrinsic amplifier noise was at a level of 0.5–0.7  $\mu\text{V}$ .

In the a posteriori regime, labels corresponding to the moments of stimulus presentation were used to select artifact-free epochs including 1-sec pre- and 1-sec poststimulus fragments. Selected EEG epochs were then averaged for each lead and subject for each of the stimuli included in the PrC, the target stimulus, and a neutral stimulus not included in the PrC (a glass), one of the stimuli (a spoon) from the PrC structure but in the status of a neutral stimulus, and also the first 30 stimuli. The resulting fragments were averaged in groups differing in terms of the effectiveness of predictive activity. When negativity was seen in the prestimulus region, the duration and mean amplitude were determined for this region. Electrographic phenomena associated with predictive activity were assessed by comparing the values obtained for the first 30 stimuli, each stimulus in the predictive sequence, the target stimuli, and the neutral stimulus (a glass) not included in the predictive sequence, and one of the stimuli (a spoon) of the prognostic structure but operating as a neutral stimulus.

**Statistical analysis.** Statistical analysis of selected artifact-free, digitized EEG fragments was run in Statistica 10.0; plots were constructed and processed in OriginLab-8.1. Assessment and interpretation of RT values (including individual values) were based on cluster analysis results (the K-mean method), correlation analysis, and the  $t$  test.

**Results. Analysis of reaction times (RT).** Mean reaction time to target stimuli for the whole group of subjects was 363.2 msec, which corresponded to the complex visuomotor reaction using an alphabet of six stimuli [Hick, 1952; Boiko, 1964]. Comparison of mean RT in young men and women using the  $t$  test showed that there were no significant differences ( $t = -0.62$ ,  $dF = 37$ ,  $p < 0.54$ ) and, thus, there was no need to consider the gender factor. The mean square deviation (105.9 msec), conversely, could not be determined only by individual features and pointed to the existence of an additional factor determining RT, which can be regarded as the presence/absence of effective prediction.

Cluster analysis of RT values using the K-mean procedure [Dyuran and Odell, 1977] showed that these were grouped into five classes (Table 1). The cluster with a mean value of 199.13 msec, corresponding to the mean time of the simple visuomotor reaction, included about 25% of all RT values. These reactions were significantly shorter than the selection reactions when there were six alternatives and can be interpreted as a special type of reaction associated with prediction of the moment at which the target stimulus would appear. Cluster analysis of individual chronograms showed that formation of predictive reactions did not occur in all subjects, such that groups with EP and NP prediction could be defined. The EP group included 11 subjects (four men, seven women), whose mean RT to the target stimulus was  $293.9 \pm 19.2$  msec. The group with NP consisted of nine subjects (five men and four women), whose mean RT

was  $432.5 \pm 37.2$  msec. The difference in the mean RT values between groups was highly significant ( $t = -4.48$ ,  $dF = 20$ ,  $p < 0.002$ ).

Predictive reactions in the group with EP formed stably after presentation of 6–12 target stimuli and consisted of series of reactions with times close to the time of the simple visuomotor reaction. Some cases showed coincident and even anticipatory reactions, though the proportion was relatively small (no more than 8% of the number of “predictive” reactions).

Analysis of the interviewing results showed that two of 11 subjects (a man and a woman) demonstrating prognostic reactions to the target stimulus did not find any patterns in series of stimuli. i.e., the presence of predictors for the target stimulus. In a number of other subject of this group, prediction reactions appeared before observation of the PrC, which followed later. Finally, in some cases, the appearance of a series of prediction reactions was followed by an increase in RT, which the subjects explained in terms of loss of interest in the situation due to its transparency.

**Analysis of CNV.** The fixed time interval between stimuli (2 sec) used in the present experiments can be regarded as a pretuning factor. On the other hand, predictors (the PrC structure) of the target stimulus operates as a prediction confidence factor. Overall, both factors allow the moment of appearance, including that of the target stimulus, to be foreseen, i.e., to operate as a basis for prediction.

Averaging of prestimulus EEG fragments recorded both before the first 30 stimuli and PrC stimuli, allowed negativity to be detected in all cases, and the parameters identified it as CNV. Differences in the parameters (occurrence time, duration, maximum and mean amplitudes) of this negativity were linked both with the leads and the stages of the experiment.

Analysis showed that negativity due to the fixed interval between stimuli arose in the interval  $-700$  to  $-100$  msec (Fig. 3, A), and was apparent on the EEG both of people with EP and those with NP. Mean CNV amplitudes in this case were  $1.7 \pm 0.25$   $\mu\text{V}$  in people with EP and  $1.05 \pm 0.17$   $\mu\text{V}$  in people with NP. These differences were statistically significant ( $t = -2.22$ ,  $dF = 19$ ,  $p < 0.038$ ). The most marked (and statistically significant) differences between groups were seen in terms of activity in the anterior (frontal temporal) and central leads (Fig. 3, B); the EP study groups had larger CNV amplitudes. These parameters were seen both with CNV recorded before the neutral stimulus (the glass) and before the stimulus (spoon) in the PrC but presented outside the prediction cue.

The time characteristics of CNV recorded before PrC stimuli (Fig. 3, C) also, in general, corresponded with those described above. Negativity was clearly apparent in the time interval  $-750$  to  $-50$  msec before the stimulus and had duration 650–800 msec, which corresponded to data reported by other authors [Bender et al., 2004; Fan et al., 2007; Gomez et al., 2007; Arjona and Gomez, 2014; Boehm et

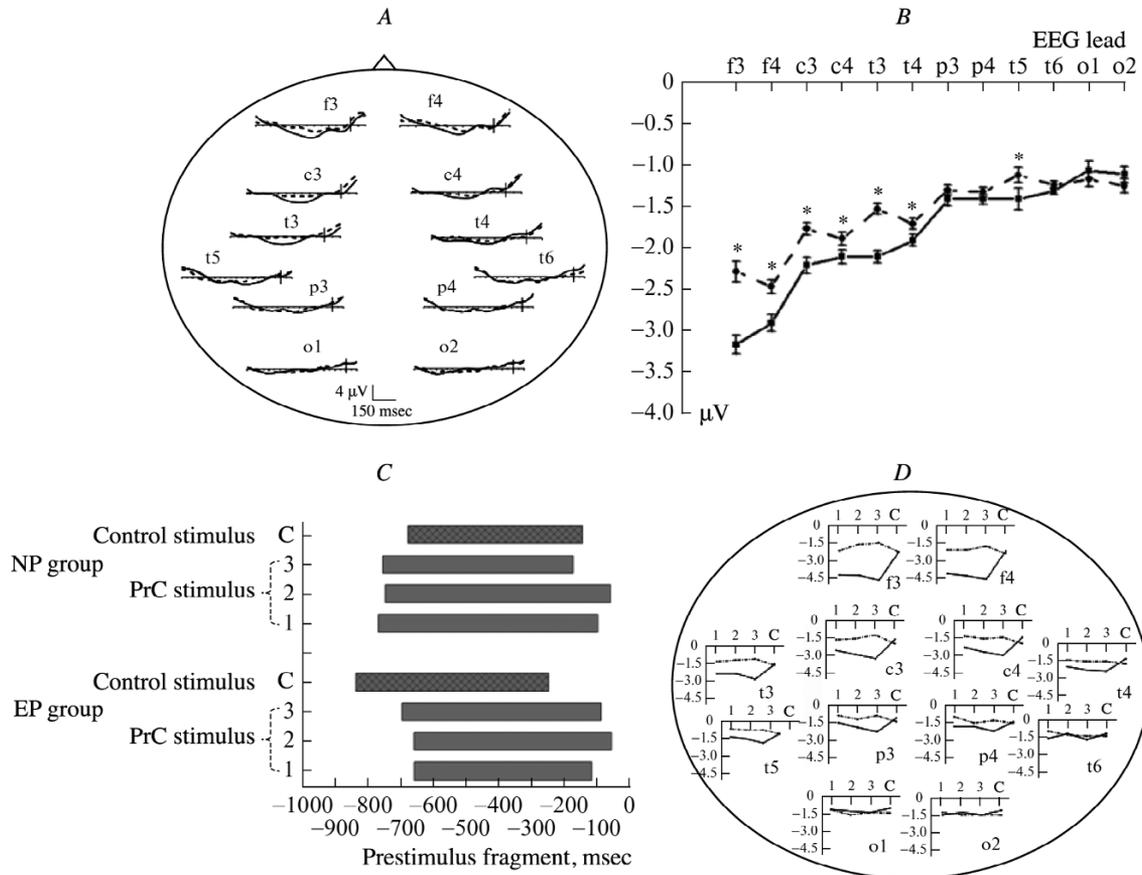


Fig. 3. Characteristics of CNV recorded before the first 30 stimuli, PrC stimuli, and control stimuli in people with EP and NP. A) Averaged CNV recorded before the first 30 stimuli; B) averaged CNV amplitude recorded before the first 30 stimuli in different leads. \*Significant differences ( $p < 0.05$ ); C) plot showing the time characteristics of CNV recorded before PrC stimuli and the target stimulus; D) plots showing mean CNV amplitudes recorded in different leads before PrC stimuli and the control stimuli. Continuous lines show the EP group and dotted lines show the NP group.

al., 2014; Pauletti et al., 2014; Hongxi et al., 2015]. In the groups with NP and EP, both the time of occurrence of this activity relative to subsequent PrC stimuli and its duration were significant ( $t = 13.4$ ,  $dF = 18$ ,  $p < 0.0002$  and  $t = -5.5$ ,  $dF = 18$ ,  $p < 0.0003$ , respectively); CNV arose later and was shorter in the EEG traces of people with EP.

More detailed analysis showed that the duration and amplitude of CNV in the EEG of people with EP arose by PrC stimuli 1–3. Changes in the characteristics of CNV in the EEG of people with NP were random in nature, analogous to what occurred before neutral stimuli. The most significant EEG changes were seen in leads f3, f4, c3, c4, t3, and t4 in people with EP and were linked with increases (by factors of 1.5–2) in amplitude from PrC stimulus 1 to stimulus 3 (Fig. 3, D).

Before presentation of the target stimulus, CNV amplitude in the EEG of people with EP showed a sharp decrease to a level even lower than that present before neutral stimuli. There were no differences in CNV parameters recorded before PrC stimuli, the control stimulus, and neutral stimuli in people with NP.

Considering that individual stimuli in PrC could also appear outside this sequence, the third stimulus was the most significant for predicting the moment of appearance of the control stimulus. Comparative analysis showed (Fig. 4) that people with EP and NP were fundamentally different in terms of the nature of the activity preceding presentation of the third PrC stimulus and the control stimulus. In people with EP, the most significant changes in activity were seen before the three PrC stimuli and the target stimulus, while such differences (compared with neutral stimulus) were virtually absent in people with NP. The mean amplitude (for all leads) of CNV in the EP group before the third PrC stimulus was  $-3.3 \pm 0.3 \mu\text{V}$ , while that before the control stimulus was  $-2.02 \pm 0.3 \mu\text{V}$  ( $t = -2.39$ ,  $dF = 19$ ,  $p < 0.02$ ), while values in the group with NP were  $-1.4 \pm 0.4$  and  $-1.8 \pm 0.3$ , respectively ( $t = 0.71$ ,  $dF = 19$ ,  $p < 0.48$ ). Comparative analysis demonstrated significant differences between groups for CNV preceding the third PrC stimulus ( $t = -3.45$ ,  $dF = 19$ ,  $p < 0.002$ ) and the absence of any differences in CNV preceding control stimuli ( $t = -0.46$ ,  $dF = 19$ ,  $p < 0.64$ ).

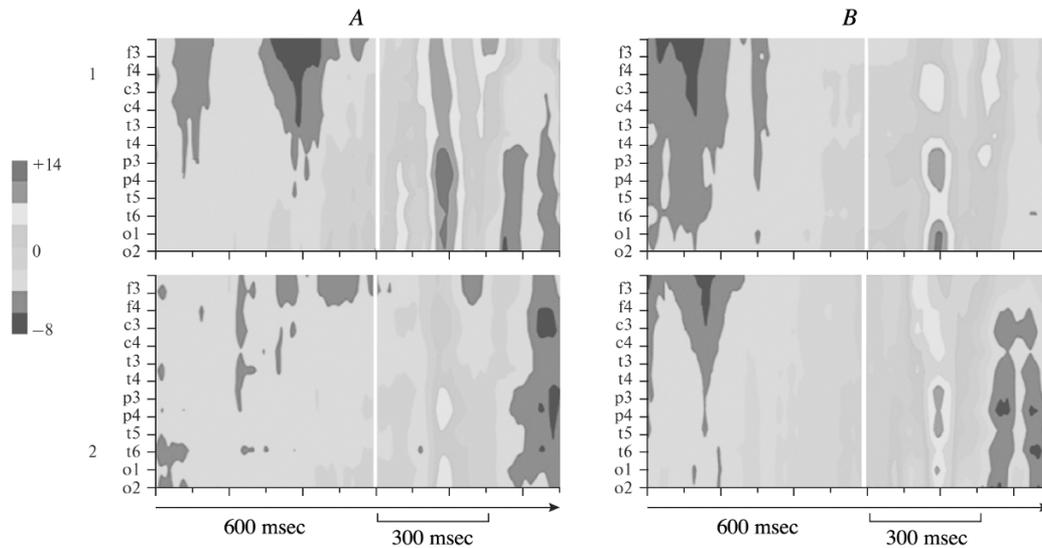


Fig. 4. Plots showing the distribution and dynamics of CNV amplitude in 2D space for the third PrC stimulus (1) and the target stimulus (2) in the EEG of people with EP (A) and NP (B). The X axis shows time and the Y axis shows leads. Color saturation levels show ranges of CNV values as defined by the scale at left.

**Correlation analysis of RT and CNV characteristics.**

Correlation analysis showed (Fig. 5) that mean CNV amplitude correlated positively with mean RT in response to the control stimulus in both NP with EP ( $r = 0.33$ ) and those with NP ( $r = 0.3$ ). This indicates that subjects with more marked negativity before stimuli had generally shorter RT. However, while people with NP showed a positive correlation between RT and CNV amplitude before both all PrC stimuli and the target stimulus, people with EP showed this CNV amplitude correlation only before PrC stimuli (most marked for the third stimulus). This latter may indicate a high level of confidence in the prediction [Fan et al., 2007; Leuthold and Jentzsch, 2001]. RT correlated most significantly with CNV amplitude recorded in leads f3, f4, and t5, reaching a level of 0.6 or more in people with EP (Fig. 5).

**Discussion.** Reaction time is known to be a universal and integral indicator of the effectiveness of perceptual and cognitive activity in humans [Hick, 1952; Boiko, 1964]. In choice situations, it depends on the length of the alphabet of stimuli and responses and cannot be less than 300 msec [Hick, 1952; Boiko, 1964; Lebedev, 1997]. Reaction time has been shown to depend on the probability with which a person expects the appearance of a significant stimulus [Feigenberg, 2008] and the existence of predictors preceding its appearance [Desantisa et al., 2014; Arjona and Gómez, 2014]. Thus, this indicator is widely used for interpreting the results of prediction activity and assessing prediction effectiveness [Fan et al., 2007; Gomez and Flores, 2011; Arjona and Gomez, 2014; Desantisa et al., 2014; and others].

We showed that on selection of one of six alternatives in the presence of predictors, supporting the ability to predict the moment of appearance of the target stimulus, the distribution of RT values included a class all of whose elements

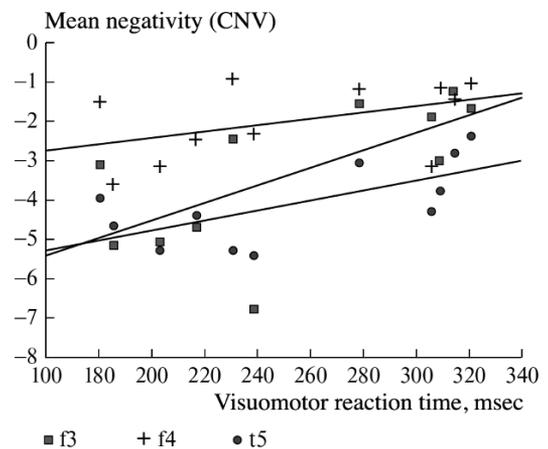


Fig. 5. Plot of the relationship between RT and mean CNV amplitude before the three PrC stimuli for leads f3 ( $r = 0.76, p < 0.02, r^2 = 0.44$ ), f4 ( $r = 0.65, p < 0.02, r^2 = 0.44$ ), and t5 ( $r = 0.69, p < 0.04, r^2 = 0.29$ ) in people with EP.

were significantly shorter than 300 msec. The non-randomness of its appearance was indicated by the fact that it included up to a quarter of all RT values recorded. The mean RT for this class was about 200 msec, which corresponds to the time of the simple visuomotor reaction [Hick, 1952; Boiko, 1964; Lebedev, 1997]. Furthermore, coincident and even anticipatory reactions were recorded in these conditions, these accounting for 5–8% of the number of “predictive” reactions. All this (along with the interview results) points to effective functioning of the prediction mechanism in people with EP, allowing them to foresee the moment of appearance of the target stimulus.

However, despite the presence of a priori information on the existence of some pattern whose observation could help support rapid reactions to the target stimulus, this

could not be done by all subjects. Almost half of them (nine of 20) could not see the pattern in the series of stimuli and did not display “predictive” reactions. This may be associated both with individual features and an insufficient level of motivation to effective activity [Regush, 2003; Sumina and Nichiporenko, 2007].

The group of people with EP was heterogeneous. Some of them (four) quite quickly (after presentation of 4–8 target stimuli) observed the predictors, consciously analyzed stimulus sequences, and unambiguously predicted the moment of appearance of the target, demonstrating rapid reactions. The chronograms of these people showed coincident and anticipatory reactions. Most people of this group observed predictors later and demonstrated stable reactions with times equivalent to the times of the simple visuomotor reaction, which is evidence for effective functioning of the prediction mechanism. Finally, two subjects of this group, not aware (judging from interview results) of the presence of a pattern in the sequence of stimuli, also clearly demonstrated “predictive” reactions. However, series of such reactions in their chronograms were shorter and alternated with reactions with a time equivalent to the time of complex visuomotor reactions. This indicates that the mechanisms of prediction can function both at the conscious and unconscious levels, as noted by other authors [Curran, 1997; Toro et al., 2005].

Despite the fact that overall, stimuli were presented in random order, the interval between presentations was fixed (2 sec). According to results described in the literature [Mento et al., 2013], this created conditions for formation of prestimulus CNV. As we have noted, this was actually formed on first presentation of the stimuli and differed in people with EP and NP; in the former, amplitude in the anterior leads was significantly greater. If we regard CNV as an electrographic reflection of expectation processes or pre-tuning [Tomita et al., 2012; Boehm et al., 2014; Pauletti et al., 2014; Rebekah et al., 2015], this points to the existence of features in people of this group which several authors have defined as prediction ability [Regush, 2003; Sumina and Nichiporenko, 2007].

The link between CNV and the effectiveness of observing visual stimuli has been demonstrated experimentally: signals were missed when CNV amplitude was minor, while false detections were recorded when CNV amplitude was high [Elbert et al., 1991; Li et al., 2014]. In the presence of predictors but the absence of the need to respond to the target stimulus, negativity was generally less marked [Fan et al., 2007]. A number of authors consider these features to reflect the subjects’ desire to respond as quickly as possible [Boehm et al., 2014]. However, our view is that this explanation is incomplete. This is indicated, in particular, by the fact that negativity (as first demonstrated by ourselves) also decreases when there is a need to react to the target stimulus if the probability of its appearance is 100% and is maximal before the predictor, which allows a highly probable predic-

tion to be made (the three PrC stimuli). All these points indicate that negativity is linked not only (and no so much) with readiness to respond, but with the functioning of the prediction mechanism and construction of a model of the situation. This is also indicated by the spatial topology of the structures most actively involved in this process, including the frontal and parietal areas of the neocortex. These areas are known to play a key role in predicting events and programming behavior [Brunia, 1999; Liang and Wang, 2003; Babiloni et al., 2006; Bubic et al., 2010; Gomez et al., 2007; Gomez and Flores, 2011; Krieghoffa et al., 2011; Chennu et al., 2013].

The original experimental model developed by ourselves allowed the process of formation of a prediction of the moment of appearance of the target stimulus in time to be developed. The first stimulus of the predictive sequence was not in and of itself the determining factor, as only in combination with others was it a predictor of the appearance of the target stimulus. The probability of appearance of the latter was 1/6 and did not change objectively even after the appearance of two PrC stimuli. Furthermore, it also did not change when the subject detected the predictor (the combination of three stimuli). Nonetheless, judging from the reports, detection of the PrC was followed by a significant increase in the subjective confidence that the control stimulus would appear after the PrC stimuli. In these conditions, as first demonstrated experimentally by ourselves, mean CNV amplitude for the series of PrC stimuli in the EEG of people with EP also increased progressively, reaching a maximum before the third stimulus and significantly decreasing before the control stimulus. Finally, these changes were most marked in the EEG of the anterior areas of cortex. In people with NP, significant changes in CNV amplitude were not seen in these same conditions. All these points lead to the conclusion that CNV amplitude reflects not the objective probability that the target event (the stimulus) would occur, but the degree of subjective confidence of the person taking the decision. As demonstrated above, this evaluation can be made both at the conscious level and at the unconscious level. The factor showing the most significant correlation with RT was the CNV amplitude recorded in the EEG of the frontal (f3, f4) and left inferior parietal (t5) leads. The special role of the frontal and parietal areas of the cortex in predictive activity has been indicated by other authors [Fan et al., 2007; Gomez et al., 2007; Gomez and Flores, 2011]. Considering that the inferior parietal areas of the left hemisphere are usually linked with the semantic and structural processing of information [Luriya, 2013], there are grounds for suggesting that the mechanism of prediction functions at the level of the subjective model of the situation is linked with the operation of this model. The suggestion that an increase in CNV amplitude recorded before PrC stimuli is linked with increases in subjective confidence in the appearance of the control signal is consistent with results from studies showing that as cues are de-

tected, the subject becomes more confident in the appearance of the control stimulus [Gratton et al., 1992; Yu and Dayan, 2005], which is consistent with the principles of probabilistic Bayesian learning [Freeman, 2003; Friston, 2009, 2010; Bubic et al., 2010; DeRidder et al., 2013, 2014]. Finally, the dynamics of the correlation between CNV amplitude and RT in the group with EP indicates that there is a nonlinear relationship between them. This suggestion has been made before [He and Zempel, 2013]. Negativity in the activity of the cortical areas due to “non-null” expectation forms when the subcortical structures involved (particularly the substantia nigra and the midbrain dopamine system) can create the conditions for integration of the relevant cortical areas in the system supporting construction of the subjective model of the situation and the probabilistic prediction. The final aim of the functioning of this system is optimization of behavior (perceptual and reactive) and the brain’s resources on the basis of transforming concepts of the situation from indeterminate to determinate. As evidenced by our results, this latter can be mediated both at the conscious and the unconscious levels and leads to optimization of the time characteristics of CNV and increases in the efficiency of activity.

### Conclusions

1. CNV arise before neutral and target visual stimuli presented with fixed interstimulus intervals, and their mean amplitude decreases from the anterior to the posterior leads.

2. The mean amplitude of CNV recorded before target stimulus predictor stimuli increases and decreases immediately before the target stimulus in the EEG of people with effective prediction.

3. The mean amplitude of CNV recorded before predictor stimuli in leads f3, f4, and t5 correlated positively with reaction times to the target stimulus.

4. We formulated the concept that CNV formation in leads f3, f4, and t5 was linked with the processes of probabilistic prediction, including that based on the construction and functioning of a subjective model of the situation.

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