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DISSOCIATION BETWEEN ATTENTION AND CONSCIOUSNESS DURING A NOVEL TASK: AN ERP STUDY

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While consciousness and attention seem to be tightly connected, recent evidence has suggested that one of these processes can be present in the absence of the other. Recent researches showed that observers can pay attention to an invisible (unconscious) stimulus, and that a stimulus can be clearly perceived (seen) in the absence of attention. We have proposed a novel psychophysical task to explore neural correlates of top-down attention and consciousness. The task is meant to confirm that these two processes can occur independently of each other. EEG was recorded during realizations of the task and target-locked event-related potentials (ERPs) for masked and unmasked conditions were constructed. Time features corresponding to the P100, N150, and P300 components were extracted for each channel separately. Utilizing these features, we employed some common classifiers for classification of the fourfold state. Our task could separate attention and consciousness successfully through their neural correlates. The results indicate that some of the mentioned components changed when attention or consciousness occurs. By comparing difference waves in each condition separately, our results introduce new ERP correlates of attention and consciousness. We also revealed that parieto-occipital areas are the most relevant areas for dissociation between attention and consciousness. To our knowledge, this is the first time that these correlates are introduced in a separable mode, and that the classification accuracies are reported for this purpose.

Keywords. top-down attention; consciousness; ERP; psychophysical task.

INTRODUCTION

Within the last part of the past century, the interest of researchers on the influence of top-down attention and consciousness on perception has steadily increased. The relevant discussions have raised the question of the relationship between attention and consciousness. Several studies have used various types of attention and consciousness, and the obtained results were different and sometimes opposite [1-4]. Both above terms refer to complex concepts, and this implies the importance of clarifying the definition of both concepts [5].

Some scholars claim that both attention and consciousness are irrefrangibly connected [6-9]. Some authors argue that consciousness is necessary for attention, while others consider attention as a prerequisite of consciousness [2, 3, 10-12]. For instance, Naccache et al. [9] stated that attention is necessary but not sufficient for consciousness. On the other hand, some recent studies showed that observers can pay attention to an invisible stimulus [13, 14], and that a stimulus can be clearly seen when attention is absolutely or nearly absent [15-17].

It is essential to consider the distinction between types of attention and those of awareness in a discussion of the relationship between attention and consciousness. In the recent literature on neural correlates of consciousness (NCC), two concepts of consciousness have been distinguished. These are phenomenal consciousness and access consciousness [18-20]. The former is defined as the case where qualitative experiences, such as simple color sensations, are present. In the visual modality, phenomenal consciousness covers the entire subjective visual field in a similar manner as iconic memory does [11]. Neural mechanisms of the contents of phenomenal visual consciousness most likely reside in the cortical extrastriate visual areas, especially

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along the ventral visual stream [11]. Reflective, or access, consciousness, by contrast, consists of only those relatively few contents of phenomenal consciousness that have been selected in an attentive mode for further cognitive processing in working memory [11]. Considering these definitions, it seems that phenomenal consciousness is a prerequisite of access consciousness. The contents of reflective consciousness can be reported verbally or otherwise expressed through any voluntary output mechanisms; these contents can be named, conceptualized, propositionally thought about, and encoded into long-term memory. Neural correlates of reflective consciousness involve modality-independent frontal areas important for the control of top-down attention and working memory; these correlate are closely connected to voluntary motor output mechanisms and access to declarative memory.

Some lines of research distinguish the relation between different types of attention and consciousness and do not generalize their results in acceptance or rejection of the relationship between these two phenomena. Hsu et al. [21] stated that "voluntary and involuntary spatial attentions interact differently with awareness." While the classical view claims that strong evidence supports the existence of a link between spatial attention and consciousness, there is evidence that spatial attention can be deployed in the absence of conscious perception of the attended information [5]. It is crucial to note that all studies reviewed by Koch and Tsuchiya [18] searched endogenous (or top-down) forms of spatial attention and awareness.

Some recent studies (e.g., [22]) in favor of afterimage effects argue that attention and consciousness can exert opposing effects on visual perception. Boxtel et al. [4] claimed that attention reduces the complexity of the incoming input so that the brain can process it online and in real time. This could be the function of the dorsal visual stream for action. The fronto-parietal area has been implicated in the control of attention, which is a part of the dorsal vision-for-action pathway and, in contrast to the ventral vision-for-perception pathway, has been linked to consciousness. These two streams interact deeply under most circumstances, but they can be dissociated under some conditions [23]. Many examples of attention without consciousness may be thought of as normal functioning of the dorsal attention-orienting system without proper functioning of the ventral system. So, an object may attract attention without giving rise to consciousness via this pathway. Similarly, consciousness without attention may occur because of some ventral functioning without help of attentive amplification from the dorsal systems [22].

Now, we propose simple and admissible definitions for both concepts. By attention, here we refer to top-down perceptual attention, which a subject would attend to as he/she intends, and not stemming from vigilance, or arousal, or any involuntary attention, as was stated by Boxtel et al. [22]. By consciousness, we refer to the content of consciousness (sometimes also referred to as awareness), and not to states of consciousness (e.g., wakefulness, dreamless sleep, or coma) as was assumed by some authors [19, 24]. In modern literature, the effects of attention are often objectively defined and measured as a reduced reaction time and improved performance. In a similar way, awareness of an object is determined as a subjective report in combination with objective forced-choice performance. With these measures in place, a variety of methods has been used to manipulate attention (cueing, divided attention, etc.) and consciousness (masking, crowding, and binocular rivalry) [5].

A typical way of making a stimulus either unavailable or available for visual consciousness is to present a mask after it with varying asynchronously presented pictures of objects or non-objects between a pattern mask that was presented before (forward mask) and after (backward mask) the stimulus. The participants were asked to decide whether the stimulus represented a target object or not [11].

Recording of event-related potentials (ERPs) is one of the most informative methods of noninvasive monitoring of the state of the brain. Therefore, evaluation of ERPs are attractive for neuroscience and, particularly, for attention-consciousness studies [19]. In the relevant works [11, 25-28], it was found that that an enhancement of the P100 wave correlates with visual consciousness. These studies were faced with the problem of possible interference between attention and arousal, as they manipulated consciousness using methods that are vulnerable to attention. This is usually acknowledged in the studies where the P100 component was reported to correlate with consciousness.

The purpose of our study was to demonstrate the distinction between phenomenal consciousness and top-down attention in a visual task. To do this, a novel psychophysical task was designed, and attention and consciousness were manipulated separately. As a result, a fourfold state was built. In order to overcome some shortcomings existing in previous studies, our task tried to eliminate the adverse effects of attending to special targets (e.g., face images); these effects accompany a peripheral task during attention (e.g., computing the number of targets). The former problem was resolved by applying a mixture of target types instead of one type, and the latter was assumed to be resolved by combining two phases of the attention time (attention only and attention together with computation). The ERP waveforms were constructed and relative ERP component features were extracted. Statistical analyses (ANOVA) were done, and three classifiers were employed in order to quantify the results. The last step was channel prioritization according to the classification accuracy.

METHODS

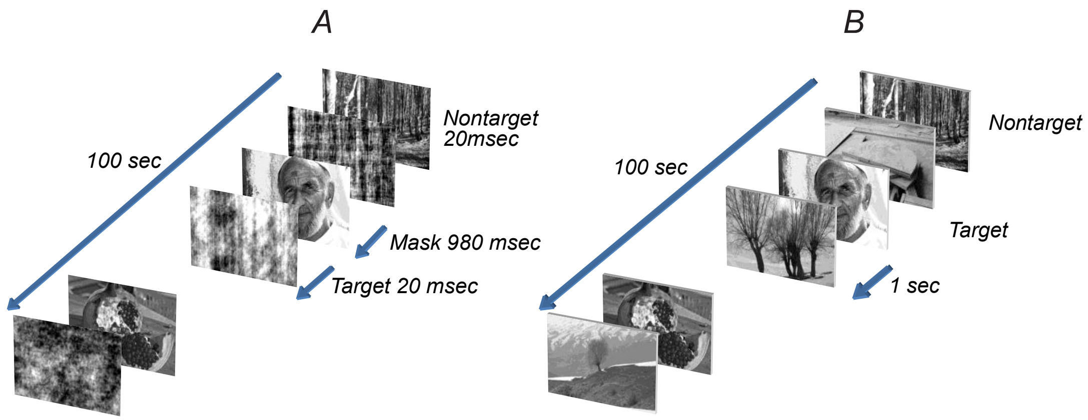
Subjects. Forty-eight volunteers (age 19 to 26 years) were involved in the study and paid for their participation. All had normal or corrected-to-normal visual acuity.

Stimuli and Procedure. The stimuli were presented on a CRT monitor with a gray background. The program was written in MATLAB software using a psychtoolbox.

We used a set of 100 images consisting of three categories of the objects (fruits, scenes, and human faces). Mask images were also created using phase-scrambled versions of the same images. The experiment consisted of four blocks, each consisting of two trials. Each image was shown in the first trial for only 20 msec followed by a 980-msec-long presentation of the mask of the same image. In the second trial, each image was shown for 1.0 sec. We used these two trials as the two states of consciousness, the first in an "unconscious" state and the second in a "conscious" state. Examples of masked and unmasked sequences for the unconscious and conscious states are shown in Fig. 1.

Four blocks were used in which the attention was manipulated. In the first and second blocks in all trials (masked and unmasked), the target was a human face for which the subjects were asked to attend. In the third and fourth blocks, the target was a fruit. In the first and third blocks, the subjects were required to attend to the target, while in the second and fourth blocks the subjects were asked to "count" the numbers of the targets in both trials.

Recording and Analysis. EEG was recorded using eight active electrodes attached to an electro-cap electrode system (g.Tec.) according to international 10/20 system sites O1/O2, PO8/PO7, P6/P5, and F3/F4. The left earlobe was used as a reference, and lead Cz was a grounding electrode. An electrode placed over the right eye was used for monitoring vertical eye movements and blinks, and two electrodes on the right side of the right eye and on the left side of the left eye were used for monitoring horizontal eye movements. EEG was filtered using a bandpass of 0.1-60 Hz, with a sampling rate of 256 sec^{-1}. A 50 Hz notch filter was used. The imped-



F i g. 1. Examples of a masked stimulus sequence for the unconscious state (A) and an unmasked stimulus sequence for the conscious state (B). Consciousness was manipulated by masking (long vs. short stimulus onset asynchrony, SOA). The target stimuli were face or fruit images; neutral stimuli were also presented. The participants were asked to be attentive and to respond to specified targets. In A) A trial was manipulated with respect to consciousness and was repeated in all blocks belonging to the unconscious state; in B) a trial had no mask and, thus, belonged to the conscious state.

Р и с. 1. Приклади замаскованої послідовності стимулів для неусвідомленого стану (А) та немаскованої послідовності для усвідомленого стану (В).

ance of the electrodes was below 5 kΩ. The baseline corresponded to the activity within a −200 to 0 msec interval preceding the stimulus onset. Trials with artifacts (>60 μV) in any of the electrodes were rejected off-line. EEG for three subjects was eliminated because of significant noise and other technical problems. A preprocessing block diagram is shown in Fig. 2.

ERP Extraction. The data acquired were analyzed using MATLAB 2008a software (Math Works, USA). In all trials, the epochs were extracted for each stimulus separately from 200 msec before the stimulus onset to 1.0 sec after the latter.

Target-locked ERPs for masked and unmasked conditions were extracted. The recorded epochs during the target stimuli were set as attention states, while others were considered inattention ones. In a similar way, the epochs during 20-msec-long stimuli were assigned as unconscious states, and 1.0-sec ones as conscious ones. Hence, there were four epoch groups constructed for each participant that produced these conditions, (i) attention with consciousness (1-sec-long target images), (ii) attention without consciousness (20-msec-long target images), (iii) consciousness without attention (1-sec-long nontarget images), and (iv) unconscious with no attention (20-msec-long nontarget images).

The epochs were averaged for targets and nontargets in aware and unaware conditions separately. The grand-average ERPs for all subjects in channels O1 and O2 are shown in Fig. 3.

ERP Components. In the statistical analyses of ERP data, we focused on the maximum amplitudes and peak latency within P100 (90-130 msec), N150 (130-300 msec), and P300 (350-700 msec) time windows [29] in occipital, parietal, and frontal leads in all four states (i.e., unconscious-inattentive, conscious-inattentive, unconscious-attentive, and conscious-attentive) in which the effects specifically related to masking (i.e., consciousness) and attention were most clearly observable. These time windows and electrode positions are similar to the ones used in previous studies [11] in which visual awareness negativity (VAN) overlapped the N150 component, and late positivity (LP) overlapped the P300 wave, whereas selective negativity [6] was observed as enhanced negativity in response to targets; it overlapped the N2 component.

Extraction of the P100, N150, and P300 Features. Because of visible differences in the waveforms of different classes in the P100, N150, and P300 components, we have defined 16 features related to the shape of the waveforms in these components for all eight channels separately [30]. All features were normalized to a zero mean and a unit standard deviation according to the relation

$$x_i = \frac{(x_i - \mu)}{\sigma} .$$

As a result, we have 16 × 8 features for the P100, 16 × 8 features for the N150, and 16 × 8 features for the P300 component.

Feature Selection. The task of feature selection is an important one involved in signal processing, when there are data with a high dimensionality or features that may not provide valuable information [31]. So, we defined a subset of features that describe the data in an efficient way. During this phase, the feature space is investigated, and different combinations of subsets are ranked by the means of class separability criteria.

Sixteen features were extracted for each ERP component in each channel. As a result there were 16 time features × ERP components × 8 channels. So, feature selection is essential for classification. There are various methods for selecting the most proper features, where the Fisher method is a common way. The idea of the Fisher method is to select a subset combination of features in a way that the between-class variance to within-class variance ratio is maximized [31]:

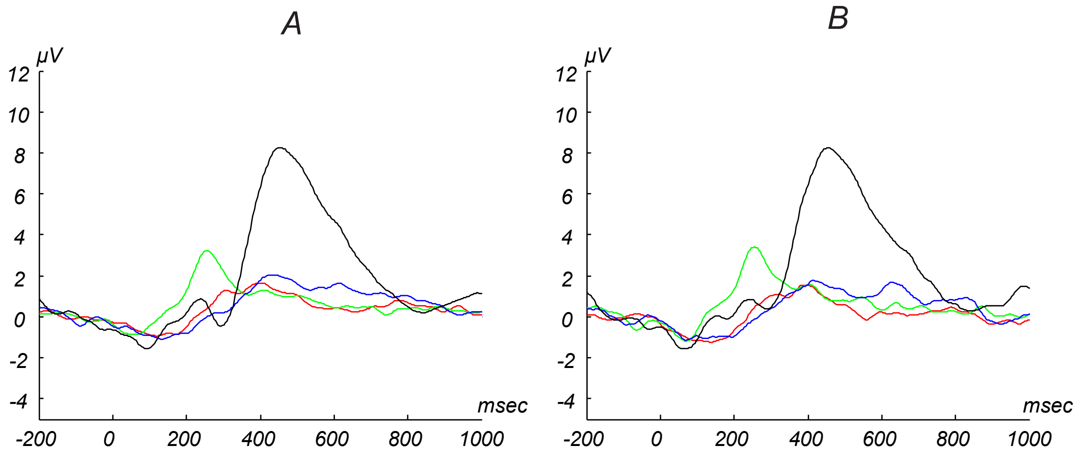
$$F_{ratio}(W) = \frac{W^T S_B W}{W^T S_W W}$$

where W is the greatest $S_W^{-1} S_B$ eigenvector, S_B is the between-class variance, and S_W is the sum of within-class variances.

Here, we have used SPSS 11.5 software for employing multi-class Fisher criteria.

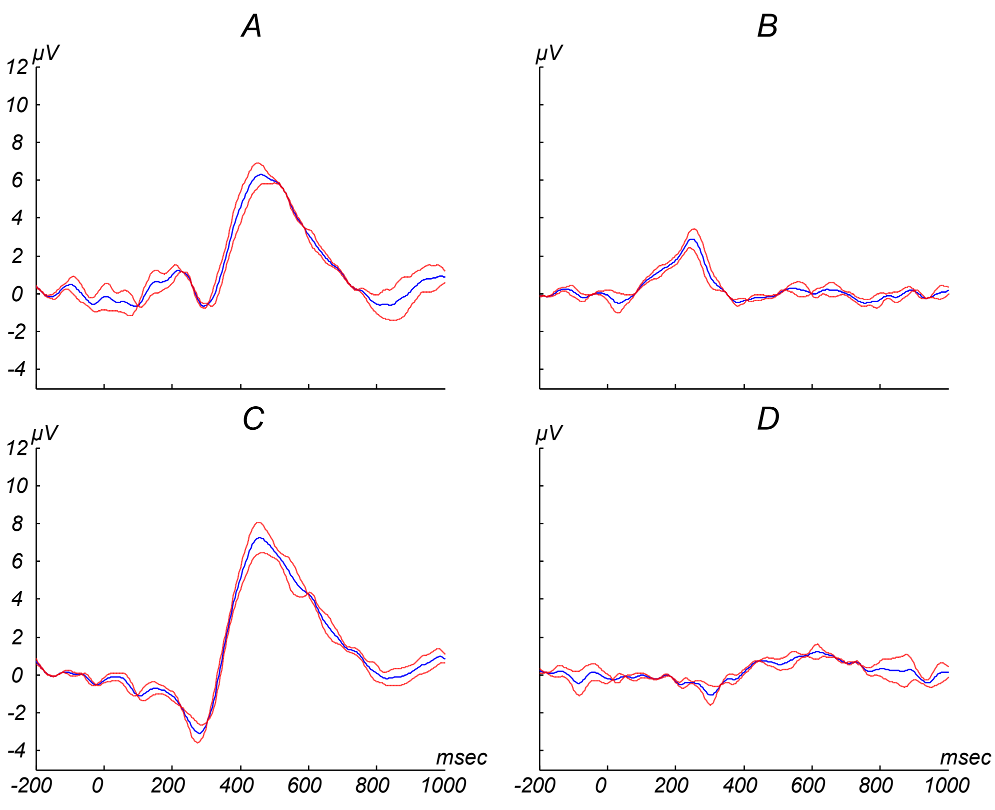
Classification. After the feature extraction and selection processes, a suitable classifier must be employed in order to separate the multiclass data. There are different classifiers, including linear and nonlinear ones. As there is no single best-classification algorithm, we have used here three powerful classifiers, (i) linear discriminant analyzer (LDA), (ii) K-nearest neighbor (KNN), and (iii) support vector machines (SVM), in order to get the best-accuracy results and also to compare these three in analyzing our own data.

Discriminant Analyzer (LDA). The idea of this classifier is to evaluate the W vector in a way that



F i g. 2. Four-class grand-average ERP waveforms recorded from leads O1 (A) and O2 (B). Traces corresponmding to the unconscious-inattentive condition are shown in red, to the unconscious-attentive condition, in blue, to the conscious-inattentive condition, in green, and to the conscious-attentive condition, in black.

Р и с. 2. Усереднені хвилі пов’язаних з подією потенціалів чотирьох класів, відведені від локусів O1 (A) та O2 (B).



F i g. 3. Grand-average difference waveforms in lead O1 (aware-unaware conditions) under attentive condition (A), under inattentive condition (B), under aware condition (C), and under unaware condition (D). Red dashed lines show the standard deviation.
Under attentive condition, increased positivities in the P100 and P300 are noticeable, while increased negativity in the N150 should be examined. Under inattentive condition, increased positivity in the P100 is observable, but its amplitude is lower than under attentive condition. Under aware condition, increased positivity in the P300 and increased negativity in the N150 are observable. Under unaware condition, increased positivity in the P300 is seen, but its amplitude is lower than that under aware condition; increased negativity in the N150 seems to be suspicious.

Р и с. 3. Усереднені диференціальні хвилі, що реєструвались у відведенні O1 за умов усвідомлення–неусвідомлення в різних умовах (A–D).

the between-class variance to within class variance ratio is maximized (Fisher criteria). As a result, g(x) is calculated from a linear relation; according to a threshold w_0, if g(x) > 0, x belongs to one class, and if g(x) < 0, x belongs to the other class.

$$g(x) = w^T X + w_0$$

K-Nearest Neighbor (KNN). The KNN is a method for classifying objects based on closest training samples in the feature space. The KNN is a type of instance-based learning where the function is approximated locally. The k-nearest neighbor algorithm is among the simplest among all machine learning algorithms. An object is classified by a majority vote of its "k neighbors," with the object being assigned to the class most common among its k nearest neighbors while k is a positive integer and is typically small.

Support Vector Machines (SVM). The SVM is a powerful classifier that uses a kernel function (i.e., f(x)) and transforms data into the feature space. The SVM finds W in such way that the distance from the nearest sample in the feature space to W is maximized [31].

In this study, we used the radial basis function (RBF) kernel in the OSU SVM Toolbox for multiclass classification.

Cross-Validation Method. The leave-one-out (LOO) is one of the most reliable cross-validation methods where one sample in each set is used for the test, and others are used for training. This process is repeated until all data get a label; as a result, the accuracy is the number of true labeled data in all sets to the total number of data.

In our study, the LOO cross-validation method was chosen in order to get robust and reliable results.

RESULTS

Analysis of the Differences between ERP Waveforms. Differences between the ERP waveforms in four states (i. e., aware-unaware in the attentive and inattentive state and attentive-inattentive, and the conscious and unconscious states) were considered for all eight recording channels. Two samples observed in leads O1 and O2 are shown in Figs. 3 and 4.

As is seen in Fig. 3, increased positivities in P100 and P300 waves are noticeable in lead O1, while increased negativity in the N150 should be examined under attentive condition. Under inattentive condition, increased positivity in the P100 is observed, but its amplitude is lower than that under attention condition. In aware condition, increased positivity in the P300 wave and increased negativity in the N150 are observable. Under unaware condition, increased positivity in the P300 is obvious, but its amplitude is lower than that under aware condition, and an increase in negativity in the N150 seems to be suspicious.

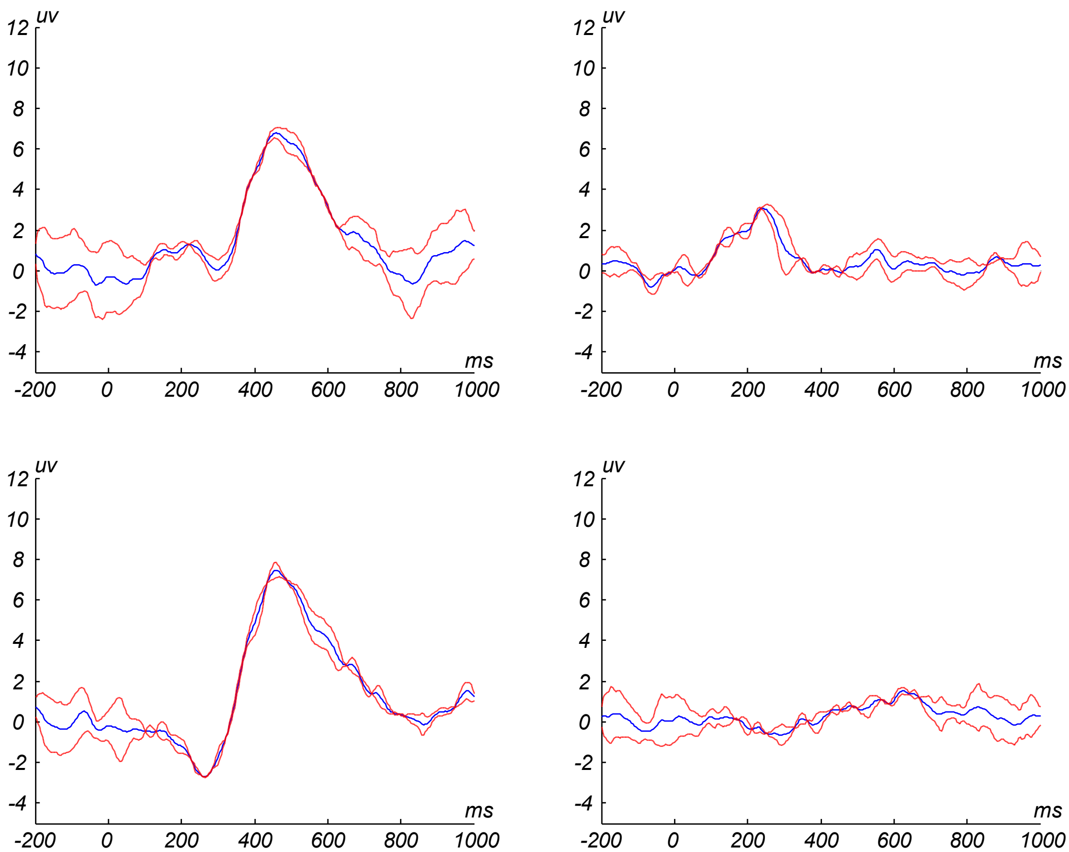
It is seen in Fig. 4 that increased positivities in the P100 and P300 waves are noticeable in channel O2 under attentive condition. Under inattentive condition, increased P100 positivity is observable, and its amplitude is higher than that under attentive condition. Under aware condition, an increase in positivity in the P300 and a corresponding negativity increase in the N150 are observable. Under unaware condition, increased positivity in the P300 should be considered.

In a similar way, increased positivities in the P100 and P300 in lead PO8 are noticeable under attentive condition. Under inattentive condition, increased positivity in the P300 component is observable, and its amplitude is higher than in the case of attentive condition. Under aware condition, increases in positivity in the P300 and that in the N150 are observable. Under unaware condition, an increase in positivity in the P300 seems doubtful.

In lead PO7 under inattentive condition, increased positivities in the P100 and P300 are obvious. Under inattentive condition, increased positivity in the P300 is observable, and its amplitude is greater than that under attentive condition. In the case of aware condition, increased positivity in the P300 and increased negativity in the N150 are observable. Under unaware condition, increased positivity in the P300 is not sufficiently clear.

In lead P6 under attentive condition, all three correlates (i.e., greater positivity in the P100 and P300 and greater negativity in the N150) are observable. Under inattentive condition increased positivity in the P100 is observed, while increased positivity in the P300 and increase negativity in the N150 are visible under aware condition. In the case of unaware condition, clearly increased positivity in the P300 is seen.

Results for lead P5 were similar to those in leads P, F4, and F3; under attentive condition all three correlates (i.e., increased positivity in the P100 and P300 and increase negativity in the N150) appeared. Under inattentive condition, higher negativity in the N150 and increased negativity within the N400 window are visible. Under aware condition, increased



F i g, 4. Grand-average difference waveforms in lead O2 (aware-unaware conditions)– under different conditions (A-D). designations are similar to those in Fig. 3. Under attentive condition, increased positivities in the P100 and P300 are noticeable. Under inattentive condition, increased positivity in the P100 is observable, and its amplitude is larger than that under attentive condition. Under aware condition, increased positivity in the P300 and increased negativity in the N150 are observable. Under unaware condition, increased positivity in the P300 should be considered.

Р и с. 4. Усереднені диференціальні хвилі, що реєструвались у відведенні О2 за умов усвідомлення–неусвідомлення в різних умовах (*A–D*).

positivities in the P100 and P300 are noticeable, and increased negativity in the N100 appeared. Under unaware condition, clearly increased negativity in the N150 should be examined.

Statistical Analysis. Event-related potentials were analyzed separately for stimuli in the attentive and inattentive visual fields by entering maximum amplitudes from the occipital (O1, O2), parieto-temporal (PO7, PO8), parietal (P5, P6), and frontal electrodes (F3, F4) into masking (masked vs. unmasked) vs. targethood (target vs. nontarget) analyses of variance (ANOVAs). Such separate analyses were considered as justified because attention vs. masking analyses separately for targets and nontargets presented to the participants showed several interactions between attention and masking within the P100, N150, and P300 time windows, indicating that attention and consciousness possess distinct electrophysiological correlates.

Peak amplitudes for the P100, N150, and P300 time windows were extracted, and the ANOVA test ($P < 0.05$) was performed separately in both aware and unaware states for all recording channels. The respective results for consciousness correlates are shown in Table 1 and for attention correlates in Table 2.

Considering the left side of Table 1. correlates of consciousness under inattentive condition, are increased positivity within the P100 window for all leads ($P < 0.05$) except frontals and increased negativity for the N150 window for channels F3 and F4. So, the correlates of consciousness in the inattentive state are increase within the P100 window in parietal and occipital leads and also increase in negativity within N150 window in frontal leads. Regarding to right side of Table 1, it is clear that

T a b l e 1. ANOVA Results for Consciousness Correlates

Т а б л и ц я 1. Результати використання ANOVA для корелятів усвідомлення

Lead	Consciousness Correlates											
	Inattentive						Attentive					
	P100		P300		N150		P100		P300		N150	
	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*
O1	27.59	0.000	0.94	0.330	1	0.300	18.2	0.000	147.7	0.000	1.45	0.230
O2	29.29	0.000	0.37	0.500	0.6	0.440	20.26	0.000	162.21	0.000	0.19	0.660
PO8	28.87	0.000	0.75	0.380	1.83	0.170	16.6	0.000	177.49	0.000	0.18	0.670
PO7	24.2	0.000	0.39	0.530	0.82	0.360	11.56	0.001	206	0.000	1.64	0.204
P6	12.7	0.000	0.35	0.550	0.01	0.927	5.98	0.016	175.49	0.000	2.96	0.080
P5	7.08	0.009	3.25	0.070	1.65	0.200	5.62	0.020	123.51	0.000	6.68	0.010
F4	1.05	0.300	2.12	0.150	55.24	0.000	12.64	0.000	38.37	0.000	21.75	0.000
F3	2.78	0.099	5.1	0.026	62.06	0.000	10.06	0.002	46.86	0.000	22.1	0.000

Footnote: Cases with *P* < 0.05 are shown dashed

T a b l e 2. ANOVA Results for Attention Correlates

Т а б л и ц я 2. Результати використання ANOVA для корелятів уваги

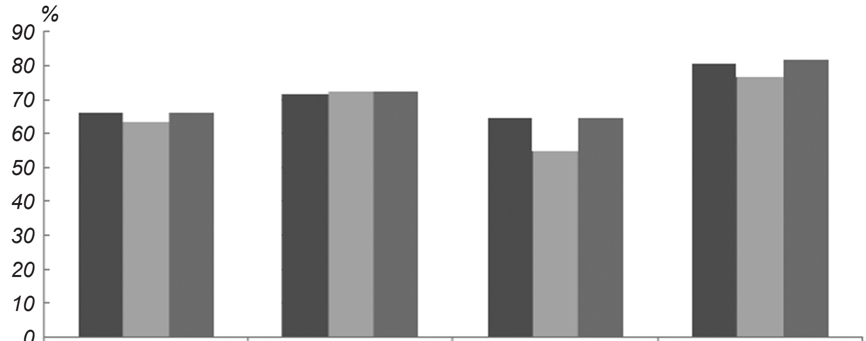
Leads	Attention Correlates											
	Unconsciousness						Consciousness					
	P100		P300		N150		P100		P300		N150	
	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*	F(1,88)	*P*
O1	1.56	0.200	7.84	0.006	3.64	0.059	1.73	0.190	159.8	0.000	12.24	0.000
O2	0.89	0.340	2.41	0.120	0.59	0.440	1.24	0.260	140.34	0.000	2.8	0.098
PO8	4.42	0.038	6.87	0.010	3.55	0.060	1.73	0.190	159.65	0.000	8.86	0.003
PO7	2.2	0.140	7.26	0.008	0.9	0.346	0.05	0.828	211.28	0.000	7.5	0.007
P6	3.17	0.070	9.34	0.003	4.41	0.030	0.42	0.510	209.67	0.000	13.78	0.000
P5	3.08	0.0825	7.63	0.007	3.97	0.049	2.08	0.150	210.07	0.000	8.88	0.003
F4	0.03	0.860	1.17	0.280	9.63	0.002	16.5	0.000	59.28	0.000	2.5	0.120
F3	0.02	0.899	0.07	0.780	6.69	0.011	17.65	0.000	76.22	0.000	0.44	0.500

Footnote: Cases with *P* < 0.05 are shown dashed

correlates of consciousness under attentive condition look like increased positivity in the P100 and P300 waves in all channels and also increased negativity within the N150 window just for P5, F4, and F3 channels. Attending to both conditions, it is obvious that the only correlate of consciousness is increased positivity in the P100 wave for parietal and occipital leads, the phenomenon called early consciousness positivity (ECP).

The analogous method is taken for ERP correlates of attention. The P300 wave increases in all relevant channels in both conscious and unconscious states, except left occipital and frontal leads in the unconscious state, and also there is an increase in negativity for the N150 for parietal leads. The other component variation (i.e., increased positivity in the P100) is, however, not found in all channels and thus should be deleted. As a result, the only significant correlate of attention is increased positivity within the P300 window, which is called late top-down positivity (LTP).

Feature Classifications of the ERP Components. Figure 5 illustrates the results for different classifications. As is shown, N150 component features have the best classification accuracies compared to two other groups (72.22% vs. 64.44 and 66.11%). This means that this ERP component has the strongest capability to separate the respective four classes.



	P100	N100-N200	P300	All
LDA	66.11%	71.67%	64.44%	80.56%
KNN	63.33%	72.22%	55%	76.67%
SVM	66.11%	72.22%	64.44%	81.67%

F i g. 5. Classification results for LDA, SVM, and KNN classifiers for the P100, N150, P300 and all feature groups.

Р и с. 5. Результати класифікації з використанням класифікаторів LDA, SVM та KNN для компонентів P100, N150 та P300 при всіх умовах.

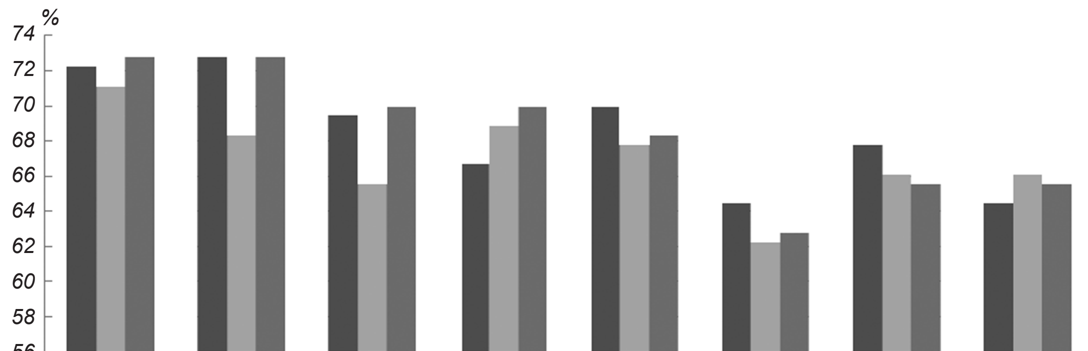
Eleven features were selected during the feature selection process from all feature groups and were used for total fourfold classification; the results are shown in the last column of Fig. 5. It shows the classification results when all three feature groups are used (i.e., P100, N150, and P300). As we can see, a combination of all feature groups provides better results (81.67%). This implies that although one of these feature sets is the best, the other sets have features with meaningful differences in fourfold states of attention and consciousness and can improve the results. As we can see, the best results are obtained from the SVM classifier.

Channel Prioritization and Classification. Another classification performed in this study was channel prioritization. We have used all feature groups for each channel separately, and the classification accuracy results are shown in Fig. 6. As can be seen in this figure, the best channels are PO7 and PO8, while F4 is the worst. By comparing the between-channel results and total classification results, it is clear that all channels bring some useful information for class dissociation. Another proof for this fact is that features that have been selected during the feature selection process belong to all channels.

DISCUSSION

In summary, the task proposed by our group has the following advantages and remarks in comparison to the previous works.

We could manipulate top-down attention and consciousness in two separate modes and produce



	PO8	PO7	O1	O2	F3	F4	F6	F5
LDA	72.22%	72.78%	69.44%	66.67%	70%	64.44%	67.78%	64.44%
KNN	71.11%	68.33%	65.56%	68.89%	67.78%	62.22%	66.11%	66.11%
SVM	72.78%	72.78%	70%	70%	68.33%	62.78%	65.56%	65.56%

F i g. 6. Classification results for LDA, SVM, and KNN classifiers for all feature groups in different channels.

Р и с. 6. Результати класифікації з використанням класифікаторів LDA, SVM та KNN для всіх умов при відведеннях по різних каналах.

four conditions. As is emphasized by Boxtel et al. [4], manipulation of attention and consciousness should be done independently. Thus, we have for the first time employed in our study different target and nontarget image types, and the latter was done by utilization of masking.

Top-down attention was manipulated by considering three types of target stimuli (human faces, fruits, and scenes), and consciousness was manipulated using masked and unmasked stimuli.

Using both types of human face and fruit images as targets eliminated the undesirable effects of attending to one special type of targets (e.g., face targets).

Another approach was considering different electrophysiological correlates of attention and consciousness obtained separately. Correlates were introduced for each concept in the presence and absence of the other by considering difference waveforms:

ANOVA results revealed that correlates of consciousness under inattentive condition, namely increased positivity within the P100 window for all channels except frontals and increased negativity within the N150 window for frontal leads. Correlates of consciousness under attentive condition increased positivities in the P100 and P300 waves for all channels and also increased negativity within the N150 window just for P5, F4, and F3 channels. Attending to both conditions, it is obvious that correlates of consciousness increased P100 positivity, called early consciousness positivity (ECP), in parietal, occipital and parieto-occipital channels and increased negativity within the N150 window just for frontal leads.

A similar approach was employed for ERP correlates of attention. The P300 increases in all relevant channels in both conscious and unconscious states except left occipital and frontals in the unconscious state, and also there is an increase in negativity for the N150 in parietal leads. Other component variation (i.e. increased positivity for P100) did not demonstrate the same results for all channels and thus is deleted.

As a result, the only correlates of attention are increased positivity within the P300 window, which is called late top-down positivity (LTP) and increased negativity for the N150 in parietal leads.

Employing three state-of-the-art classifiers, we quantified our results, i.e., features corresponding to all three time components were extracted, gathered, and used for classification after the feature selection process. The best result was obtained by SVM (81.67%). This high-accuracy result reveals the power of the task and also the respective time features.

Features corresponding to each time window were classified separately, and the highest-accuracy result belonged to the features corresponding to the N150 window. As a result, this time window should be considered the most meaningful one.

Another processing was done for choosing the more relevant channels. In this respect, features for each channel were classified singly and channels PO7 and PO8 were introduced as the most appropriate ones.

The findings from this experiment support our hypothesis, namely, that one should distinguish more carefully between different types of attention, as well as different forms of consciousness, when describing the relationship between attention and consciousness. While bottom-up attention seems to be strictly connected to awareness, top-down attention is not necessary for consciousness. In other words, there are conditions under which top-down attention or awareness can occur in the near absence of the other.

Our results provide additional insight into the relationship between the above-mentioned two phenomena. Due to the novelty of our task and type of processing used, exact comparison cannot be done, but there are considerable similarities (and also differences) between our results and those of the respective previous works [11, 18, 19, 22, 27, 32]. Although there were P300 and N150 variations in the attentive field similar to [11, 33], we could report only the P100 for parietal, occipital, and parieto-occipital channels and increased negativity within the N150 window just for frontal leads as ERP correlates of consciousness because we have considered both attentive and inattentive fields. The affected areas for consciousness were parietal, occipital, parieto-occipital, and frontal areas. Again, it was expected to have the N100-200 component as a correlate of attention (according to [11]),but in our study, the N150 component was valid for only parietal areas, and also the P300 component was valid for parietal and parieto-occipital and right occipital ones. So, as was discussed in [4], "attention to a stimulus or an attribute of this stimulus is neither strictly necessary nor sufficient for the stimulus or its attribute to be consciously perceived."

Another approach considers different electrophysiological correlates of attention and consciousness obtained separately. These ERP correlates were obtained from difference waves (aware/unaware) in the presence and absence of attention for correlates of consciousness and (attentive/inattentive) in the presence and absence of consciousness for correlates of attention.

Here, we have tried to quantify the distinction by means of classification the ERP component features extracted from ERP signals in four states, which are unconsciousness with no attention, consciousness without attention, attention without consciousness, and consciousness with attention. These features are related to the P100, N150, and P300 components, which are extracted according to waveform differences and statistical results. The SVM, KNN, and LDA classifiers have been used for this purpose, and the results revealed that all three P100, N150, and P300 waves are meaningful components when distinguishing between these two processes, and N150 component features are stronger than those of the other two groups. This is the first time that these quantification results are mentioned. Employing such simple features corroborates our assumption on the inherent separation between the above two phenomena.

Another approach is related to meaningful channels. The results revealed that channels PO7 and PO8 are the best leads for distinguishing between attention and consciousness manifestations, while all channels have meaningful ERP component features, which can help in the classification.

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All procedures were in accordance with the ethical standards of the responsible committees on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all subjects included in the study. All participants were volunteers; they were informed in detail on the pattern of the experiment.

The authors of this study, R. Davoodi, M. H. Moradi, and A. Yoonessi, confirm that the research and publication of the results were not associated with any conflicts regarding commercial or financial relations, relations with organizations and/or individuals who may have been related to the study, and interrelations between co-authors of the article.

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ДИФЕРЕНЦІАЦІЯ ЕФЕКТІВ УВАГИ ТА УСВІДОМЛЕННЯ В НОВОМУ ТЕСТІ: ДОСЛІДЖЕННЯ З ВИКОРИСТАННЯМ ПОТЕНЦІАЛІВ, ПОВ’ЯЗАНИХ З ПОДІЄЮ

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Р е з ю м е

Як вважають, увага та усвідомлення тісно поєднані, проте результати недавніх досліджень дають підстави думати, що один із цих процесів може реалізуватися за відсутності другого. У новітніх експериментах виявилося, що спостерігачі можуть приділяти увагу невидимому (неусвідомлюваному) стимулу і що стимул може чітко розпізнаватися (диференціюватися) за відсутності уваги. Ми запропонували нове психофізіологічне завдання для дослідження нервових корелятів змін рівнів уваги та усвідомлення. Цільові ЕЕГ-потенціали, пов’язані з подією (ППП), відводили в умовах пред’явлення замаскованих та незамаскованих візуальних патернів. Часові характеристики компонентів Р100, N150 та Р300 визначалися роздільно для відведень по кожному ЕЕГ-каналу. З урахуванням цих характеристик були використані певні загальні класифікатори для параметрів, спостережуваних у всіх чотирьох стимуляційних станах. У нашому тесті ефекти уваги та усвідомлення могли бути успішно розділені відповідно до їх нервових ЕЕГ-корелятів. Згідно з отриманими результатами, згадані вище компоненти ППП змінюються залежно від того, як проявляється увага або усвідомлення. Роздільне порівняння відмінностей між хвилями ППП для кожної з умов дозволило виявити нові кореляти уваги та усвідомлення, що відбиваються в ППП. Показано також, що тім’яно-потиличні кортикальні зони є структурами, найбільшою мірою пов’язаними з дисоціацією ефектів уваги та усвідомлення. Як ми вважаємо, ці кореляти вперше представлені з використанням методики, котра дозволяє їх розрізнити, і наведені дані щодо точності такої диференціації.

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