Unconscious Context Control of Visual Perception of Simple Stimuli: A Study Using Evoked Potentials

E. V. Levichkina[a,b] and A. Ya. Kaplan[a]

[a]Moscow State University, Moscow, 119992 Russia

[b] Institute for Information Transmission Problems (Kharkevich Institute), Russian Academy of Sciences, 101447 Russia

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Abstract—The effect of nonsemantic context on the perception of simple nonverbal visual stimuli has been studied in ten healthy volunteers by the event-related potential (ERP) method. The nonsemantic context was specified by the formation of a memory trace of a test visual stimulus via its repeated presentation without any instruction except gaze fixation. Then, this stimulus randomly alternated with control stimuli that did not form memory traces before their presentation. It has been found that an ERP in the interval 260–340 ms after presentation of a simple nonverbal stimulus significantly differs from the control ERPs. The results suggest that some stages of the processing of visual stimuli may be modified by nonsemantic context.

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INTRODUCTION

It is well known from experimental psychology that the same stimuli may be differently perceived and induce different behavioral responses depending on the unconscious context information [1–3].

EEG studies have clearly demonstrated these effects by the method of event-related potentials (ERPs), the amplitudes of whose late components change depending on whether the sensory stimuli were presented for the first time or repeatedly [4].

In these studies, masking stimulation prevented the subjects from consciously registering their priming with some of the stimuli [5–7].

These and other data suggest that analysis of the same stimuli may yield different results, depending on unconscious personal experience and priming the subject with context stimuli. It has been hypothesized that there are two different systems of memory, explicit and implicit memory, which serve for realized and unconscious contexts of perception, respectively [8].

However, what is the context that helps to automatically "sort" stimuli into more and less pertinent to this context even at the unconscious level? Almost all paradigms appealed to the semantic context and used, as a rule, words, images of different object categories, etc. as stimuli. However, will the effect of context remain if the stimuli that form this context are deprived of semantic attributes?

In this work, we attempted to find out whether unconscious context-based "control" was limited by the perception of stimuli by semantic filters or this control was retained even if the stimuli lacked strong semantic context.

Tulvig and Schacter hypothesized that implicit memory may be actualized at the level of the presemantic presentation of stimuli [3]. The results of manipulations with the meaning of stimuli were contradictory. In the experiments with meaningless shapes and mixed pictures, the effectiveness of context in perception was almost eliminated [9, 10]. However, the effect of context on perception was demonstrated through the comparison of mixed and normal images [10].

Thus, the question of the necessity of semantic attributes of stimuli for the formation of effective context of perception remains open. Hence, in this work, we studied whether the known effects of context-determined changes in the ERPs would be induced by very simple stimuli that are not verbalized during their perception.

EXPERIMENTAL

Ten volunteers (four men and six women) took part in the study.

The EEG was monopolarly recorded at 15 electrode locations (O_1, O_2, P_3, P_4, T_5, T_6, T_3, T_4, C_3, C_4, Cz, F_3, F_4, F_7, and F_8), with linked earlobe electrodes serving as a reference electrode, at a frequency of 500 Hz. The visual stimuli were flashes (0.15 mcd × 4, 20 ms) of four AL307 red light-emitting diodes set in different patterns. A fifth light-emitting diode was located at the center of the visual field and served as a permanent point of fixation; each of the four other diodes was located in a single quadrant of the visual field and was a vertex of a quadrangle with unequal sides. We used patterns of two angle sizes (referred to below as small and large) for controlling the effect of eccentricity of the stimuli. The projections of the stimuli of the small and large patterns on the retina were located at a dis-

tance of 2.3–4.6 and 4.6–9.1 angular degrees from the center, respectively; i.e., in both cases, they were in the extrafoveal area of the retina [11, 12]. The duration of stimulus presentation was 20 ms. After that, the response to the stimulus was recorded for 700 ms, which was followed by a random interval of 50–400 ms.

The context of perception was formed by repeated presentation of the same stimulus without any instruction, except gaze fixation, at the beginning of a session. Then, this stimulus was randomly alternated with other stimuli that had not been presented before. One session included two parts: at the beginning of the session, the same *repeated* stimulus was presented 25 times in a row; then, in stochastic order, a subject was presented with the same stimulus as a *test* stimulus and two *control* stimuli (which had not been presented before). Each stimulus occurred 25–30 times in a series. The central light-emitting diode, which was used as a point of fixation, had a constant brightness two times lower compared to the other diodes. Each subject participated in eight sessions (eight EEG recordings) and different stimulus patterns were used in each session. The sessions were grouped in two series of four recordings, separately with patterns of small and large sizes. Thus, the unconscious context of visual stimuli was that one of these stimuli formed implicit models via its isolated repeated presentation.

Single ERPs were preliminarily smoothed by averaging the EEG in consecutive 8-ms frames (four samples) and further averaged for each type of condition; i.e., we obtained averaged *repeated*, averaged *test*, and two averaged *control* ERPs in each session. Then, we averaged ERPs of the same type for each subject in each of two series (with large and small stimuli). Thus, for each subject, according to the results of each series, we obtained averaged ERPs of three types: *averaged repeated, averaged test*, and two *averaged control* ERPs. After a visual evaluation of the differences, we selected an interval of 400 ms from the moment of stimulus presentation; this interval contained 50 time counts after averaging.

Statistical analysis included a comparison of amplitudes of all types of ERPs with one another. To this end, we formed pairs of compared ERPs: test–repeated, test–control 1, test–control 2, repeated–control 1, repeated–control 2, and control 1–control 2. Analysis included statistical evaluation (Wilcoxon's test) of the hypothesis on the nonzero difference between the average amplitudes of ERPs in pairs for each of 50 points from the time series of ERPs. Evaluation of each pair of compared stimuli was performed in all subjects in all 15 EEG electrode locations. After that, we generalized the statistical differences in ERP pairs taking into account the sign of the difference.

RESULTS

The analysis has shown that, within 260–340 ms, significant differences ($p < 0.05$) in the ERP amplitudes in response to test stimuli and other types of stimuli appeared. In this interval, the test-induced ERPs with preliminarily formed memory traces were more negative than the ERPs caused by repeated stimuli and more positive than the ERPs in response to control stimuli. The control stimuli did not differ from one another. The differences were similar in both series and appeared in the parietal–central–frontal areas of the right hemisphere.

The amplitude differences found are shown in figure a; they are exemplified by ERPs induced by repeated, test, and control stimuli for series 1 (presentation of small stimuli) and averaged over all subjects for electrode *Cz*. Figure b schematically shows the topography of the significant differences obtained. An increase in the number of statistical comparisons inevitably results in the appearance of false results. Therefore, we took into account differences in the ERP amplitude only in the cases when the adjacent intervals (samples) contained significant differences ($p < 0.05$) of the same sign, i.e., the ERP in response to one stimulus type in two adjacent samples was larger (or smaller) than the ERP induced by the other stimulus type. For each derivation in both series, the differences are shown in the summary table (figure b) as follows: each cell of the table corresponds to two adjacent 8-ms samples, a cell is dark-gray if both samples contained significant differences of the same sign and light-gray if the differences were found only in one of the adjacent samples.

It can be seen that the ERP induced by a test stimulus in the interval 260–340 ms after stimulus presentation is very similar in shape to the ERP induced by a repeated stimulus and differs from the ERPs induced by control stimuli. This suggests that a stimulus passively memorized after a large number of presentations without any task to solve is assessed at the level of the cortex differently from the stimuli not presented before.

DISCUSSION

It is known that a number of components of visual ERPs, which occurs during late intervals after stimulus presentation, 200–800 ms, are related to recollection [13–16]. According to the literature, visual ERPs in the interval 150–300 ms after stimulus presentation reflect the first effects associated with recognition and analysis of images [17, 18].

This is highly possible for the *P*300 peak, because differences between ERPs in this interval may be related to recollection and comparison. The *P*3*a* component, which appeared within approximately 300 ms after the moment of stimulus presentation, is associated with the development of an absolutely unexpected "surprise" stimulus [19]. The *P*3*a* generation was related to the involvement of the frontal cortex [20], and its appearance depends on the integrity of the frontal cortex [21]. This component is considered to be identical to the so-called Novelty *P*3 or *P*3 one appearing in the

tasks of the isolation of unfamiliar stimuli (the *old/new* paradigm) [22].

There are several components that respond to the novelty or familiarity of stimuli in the *old/new* paradigm. All of them have larger positivity of ERPs in response to familiar stimuli as compared to novel stimuli [23, 24]; however, they differ in topography and depend on the task.

It has been shown that the earliest visual *old/new* effects are developed in the interval 170–260 ms from the moment of presentation of the stimulus, and the focus of these effects is located in the occipital–temporal area. This is the so-called visual memory potential (VMP) identified by Begleiter et al. [25]; its appearance is related to the functioning of short-term memory.

Later *old/new* effects are the frontal effect in the interval 300–500 ms and the parietal effect in the interval 400–800 ms. The *old/new* effect in the interval 300–500 ms is often referred to as *FN*400 *old/new* effect [25–27], because it is similar to the *N*400 component of the semantic mismatch, however, the *old/new* effect is usually distributed more frontally than the centroparietal effect of the semantic mismatch. The late *old/new* effect is usually referred to as the parietal *old/new* effect [28, 29] (for review, see [30]).

Recent studies have shown that the component in the interval 300–500 ms is associated with processes of determination of global similarity, and the later component in the interval 400–800 ms is related to the recollection of information on the detailed features of an object [29, 31].

In our work, ERPs induced by new control stimuli at about 300 ms after the stimulus onset were more negative, and ERPs caused by the test stimuli with memory trace were more positive, with the level of their positive deviation approaching the ERPs induced by repeated stimuli. In other words, we observed an effect similar to the *old/new* effect. According to spatiotemporal characteristics, the new component is similar to both visual memory potential and *FN*400 *old/new*. Presumably, this component is composite; its onset may be related to the occipital–parietal area, and activation of the frontal area occurs a little later.

In our case, the *old/new* effect was distributed predominantly in the right hemisphere and has a focus in the right centroparietal area, which is in agreement with the data on lateralization of the *old/new* effect in the case of the presentation of word stimuli and object-image stimuli. It has been shown that, during the recognition of images, the *old/new* effect appears in the temporal area about 180 ms after the stimulus presentation and reaches a peak at a time point of 240 ms, whereas during recognition of words, it appears in the interval 300–400 ms after stimulus presentation and is more pronounced in the left temporal and both frontal areas [10]. Thus, in the right hemisphere, differences between the ERPs induced by passively memorized and new stimulus may be associated with the fact that the stimuli used in our experiments cannot be verbalized. This gives additional evidence for regarding the differences found as the manifestation of visual processing, which is presumably associated with passive memorization of patterns and their extraction from memory.

Traditionally, tasks involving the development of specific memory-related components of visual ERPs included the imperative attraction of the conscious attention of a subject to a recognized stimulus or its specific characteristic, i.e., active memorization of the stimulus. The majority of studies on the *old/new* effect considered only differences associated with the presentation of words or easily verbalized images in the tasks for the recognition of consciously memorized objects. It is obvious that, under the conditions of natural behavior, objects are predominantly memorized without conscious attention. Moreover, many of these objects have no verbal equivalents or semantic attributes for the subject. This creates the unconscious context of visual perception. Is it possible to find the presence of unconscious context, i.e., experience formed without conscious effort, in ERPs?

Previous experiments with the presentation of unrecognizable and impossible objects did not demonstrate *old/new* effects [10]. However, we note that, in the paradigms used, a large number of test objects (about several hundred) were presented, and each object was presented only a few times. Under these conditions, it is hard to expect any effects associated with memorization of complex nonverbal objects. However, under the conditions when the subjects can conveniently adjust the context control using simple repetition of the same simple nonverbalized stimuli, the *old/new* effect may occur.

Differences between the amplitudes of ERPs induced by test and other stimuli. (a) ERPs to test stimuli (the black line), repeated stimuli (the thick gray line), and control stimuli (control 1, circles; control 2, triangles) averaged over ten subjects for the *Cz* electrode in series 1 (small stimuli). The abscissa shows the time from the moment of stimulus presentation in milliseconds; the ordinate shows the amplitudes of the averaged ERPs. (b) The topography of significant differences ($p < 0.05$) found when comparing all ERP amplitudes in series 1 (small stimuli). The tables on the right show significant differences for electrodes O_2, P_4, C_4, Cz, T_4, and F_4. Each cell of the tables corresponds to two adjacent samples of 8 ms; the time intervals from the moment of stimulus presentation are shown in the first column. Comparisons between ERPs in response to repeated stimuli and ERPs in response to test stimuli are designated r–t; those between ERPs in response to test stimuli and control stimuli are, t–c1 and t–c2, respectively; and those between ERPs in response to control stimuli, c1–c2. A cell is dark gray if the adjacent samples had significant differences of the same sign and light gray if the differences were found only in one of the adjacent samples; in the absence of differences, the cell is white. The results for series 2 (large stimuli) are shown in the same format.
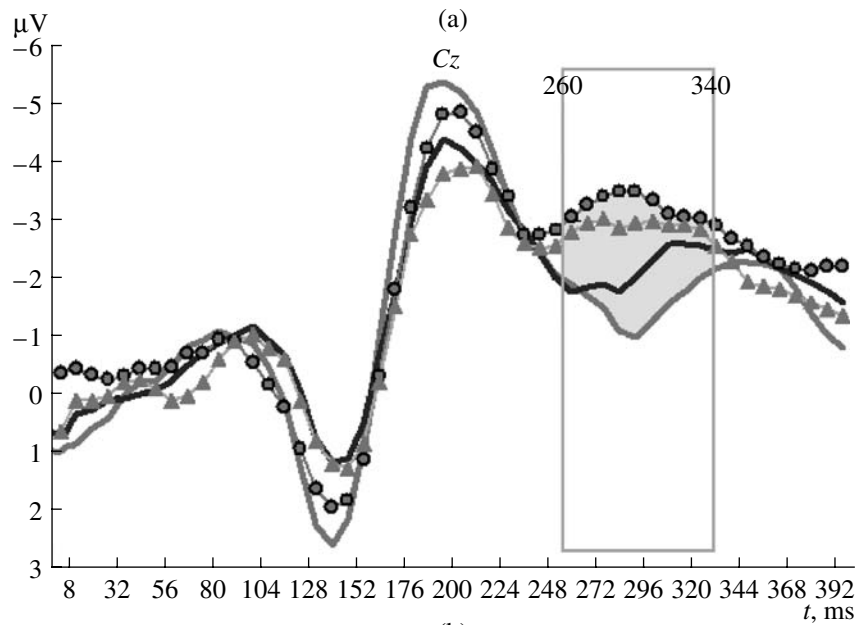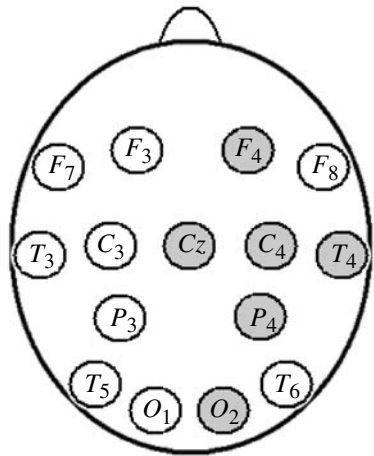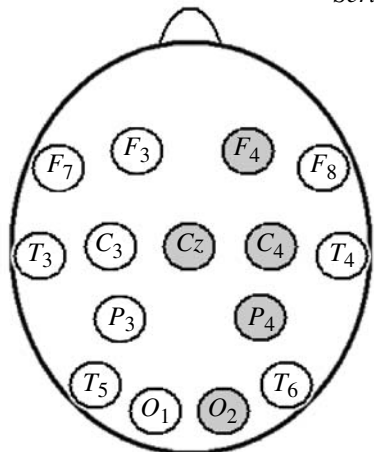
(a)

(b)

Series 1

O2s	r–t	t–c1	t–c2	c1–c2
260–276				
276–292		▓		
292–308	▓	▓		
308–324	▓	▓		
324–340				

F4s	r–t	t–c1	t–c2	c1–c2
260–276				
276–292		▓	▓	
292–308		▓	░	
308–324		▓		
324–340				

P4s	r–t	t–c1	t–c2	c1–c2
260–276				
276–292		▓	▓	
292–308	▓	▓		
308–324		▓		
324–340	▓			

T4s	r–t	t–c1	t–c2	c1–c2
260–276			▓	
276–292		▓	▓	
292–308		▓		
308–324		▓		
324–340				

C4s	r–t	t–c1	t–c2	c1–c2
260–276		░		
276–292		▓	▓	
292–308		▓	▓	
308–324		▓	░	
324–340	░			

Czs	r–t	t–c1	t–c2	c1–c2
260–276				
276–292		▓	▓	
292–308	░	▓		
308–324				
324–340				

Series 2

O2l	r–t	t–c1	t–c2	c1–c2
260–276	░			
276–292			▓	
292–308		▓	▓	
308–324				
324–340				

F4l	r–t	t–c1	t–c2	c1–c2
260–276				░
276–292				
292–308				
308–324		▓	▓	
324–340				

P4l	r–t	t–c1	t–c2	c1–c2
260–276				
276–292				
292–308	▓	▓	▓	
308–324	▓	▓	▓	
324–340	░	░		

T4l	r–t	t–c1	t–c2	c1–c2
260–276				
276–292	░			
292–308				
308–324				
324–340				

C4l	r–t	t–c1	t–c2	c1–c2
260–276				
276–292				
292–308		░	▓	
308–324			░	
324–340		▓		

Czl	r–t	t–c1	t–c2	c1–c2
260–276				
276–292	▓			
292–308		▓	▓	
308–324		▓		
324–340		▓	░	

Thus, in the absence of attention of a subject to any characteristic of a stimulus that, in addition, has no semantic attributes, its multiple repetition results in the formation of a nonsemantic context, which can be seen as the differences in the ERPs induced by stimuli that are relevant and irrelevant to the context formed.

CONCLUSIONS

(1) The method of ERPs permits the evaluation of the effect of nonsemantic context on the perception of visual stimuli.

(2) The effect of unconscious context during the presentation of nonverbalized stimuli is seen as an increase in positivity in the 300-ms interval after the presentation of a familiar stimuli.

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