The impact of object organization and its attentional modulation in a visual scene

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Abstract. Two objects are presented simultaneously, defined by shape and color, which suffer some mutations in certain local features, to measure the attentional blink’s (AB) effect, which is evident in case of different-object transitions. Results proof that the attentional transitions established between two features of a single object are easier than transitions between two features belonging to different objects, and, in addition, this isn’t a homogeneous effect on the visual field, so there is a favored hemi field in such transitions. A N230 component is obtained with higher amplitude for same-object transitions in relation with different-object transitions. These results are compared with other design that separate the mutant attributes from base figures, and then the behavioral effect is annulled.

Keywords: Visual attention, object organization, atencional blink, RSOT, ERP.

1. Introduction

In every scene there are several objects, each one with different features like color, form, motion, etc. Normally, it’s hard for the human visual system to process all this information with the same priority. Because of this, it is necessary a mechanism for prioritizing some information sources among several others. This mechanism is called selective attention. A common design for studying selective attention is the attentional blink paradigm. In one of its variants two different stimuli are presented successively and individuals have to perform a discrimination task related with some of their features. Those stimuli may be located on the same object or be part of different objects. If the time interval between them is lower than 400 – 500 ms subjects fail to perform the task to the second stimulus, but that failure is eliminated if the first stimulus is not attended. On the other hand, the evoked potentials elicited by attentional transitions between parts of the same object show higher amplitudes when compared to spatially equivalent transitions between different objects [Duncan, 1984; Vecera and Farah, 1994; Lavie and Driver, 1996; Berhman, Zemel and Mozer, 1998; Valdés-Sosa, Cobo and Pinilla, 1998]. This effect is probably reflecting a higher activation level of some neuronal groups representing the attended object and a relative suppression of other groups representing initially unattended objects in the visual pathway. This sort of evidence is used in paradigms including the presentation of two or more objects defined by a group of features. Subjects are instructed to perform a
discrimination task in two targets located in the same or in different objects. In our study a similar design is used with a Rapid Serial Object Transformation (RSOT) paradigm. These transitions should be easier when taking place between parts of the same object in contrast with those between different objects. The event-related potentials are expected to show lower amplitudes in this last situation.

2. Experiment 1

In this experiment the subject’s electrophysiological performance was explored by using a discrimination task between changes in the same or in different objects.

2.1. Materials and Methods

Participants

Nine subjects, 4 of them men, all from the Cuban Center for Neuroscience, participated in this experiment. All of them were right handed (by personal report), aged between 24 and 36 years (mean = 28 years), had normal or corrected-to-normal vision and none of them had reported abnormalities for color vision nor had a history of neurological or psychiatric disorders.

Procedure

Visual stimuli were displayed in a SVGA 12” monitor, on a black background, 60 cm away from the observers. They consisted in two figures: an ellipse, colored in grey, and a “horseshoe”, colored in red. Two possible object configurations were used (Fig. 1), one with the ellipse on the right side of the horseshoe and the other with the ellipse on the left side. Five black rhombus-like holes (7 pixels wide) were also included in these figures, one in a central position of both configurations (in the ellipse, on the half part close to the horseshoe) and the rest peripherally distributed (up, down, left and right) and equidistant to the central one. The subjects were instructed to identify changes in those holes as random disappearances (3 pixels deep) of one of the corners, first in the central rhombus (T1) and later in one of the peripheral ones (T2), representing a partial occlusion of those holes.

The participants in our study were asked to attend to both figures and fixate their gaze on the central rhombus in a baseline with no change. The experiment was triggered by the spacebar of the computer’s keyboard. The stimulus onset asynchrony was set in 380 ms and T2 lasted for another 100 ms. Two sessions were used for each subject, each one including 800 trials and 10 different conditions. For every ellipse-horseshoe configuration 4 combinations of central rhombus-T1 and peripheral rhombus-T2 were used. In addition for every configuration trials with only T1 events were introduced for subtraction purposes.
The psychophysiological data were re-codified and analyzed using the software STATISTICA 98 (version kernel 5.1) taking into account only T2 answers preceded by correct T1 answers. A repeated-measures ANOVA was then applied to evaluate two effects: configuration type and T2 position.

Two recording sessions were run for each subject. In the first session the EEG was recorded by using Ag/AgCl electrodes in 6 active derivations included in the 10/20 international system referenced to nose as part of a MEDICID 32 system (Havana, Neuronic SA). In the second session the EEG was recorded by using a high-density 128 channel MEDICID 128 system (Havana, Neuronic SA).

In both sessions, 4 derivations were used for EOG recordings, two in the external edge of both eyes (horizontal movements) and two 1 cm above and below the left eye (vertical movements). Impedances were kept below 5$k\Omega$ prior to data acquisition. Data were recorded at a sampling rate of 200 Hz and filtered between 0.05 and 30 Hz. Data analysis was performed with EP Workstation (Havana, Neuronic SA). EEG was segmented offline in epochs of 800 ms duration (-100 to 700 relative to T2 presentation). All segments were visually inspected and those containing non-stereotyped artifacts (e.g., swallowing, cable movements, etc.) or eye blinks occurring during target presentation were discarded. Segments from each condition were separately averaged for each subject. Grand averages were calculated for each condition across subjects.

The isolated response elicited by T2 presentation was obtained by subtracting the event-related potentials (ERPs) from trials with T1 only from the ERPs elicited by the rest of the trials that included both configurations. Difference waveforms were calculated for O1 and O2. The ERPs elicited by transitions between parts of the same object (ellipse-ellipse) and between different objects (ellipse-horseshoe) were analyzed by using a permutation test, applied to the individual average potentials for each condition, setting the threshold of significance at $p = 0.05$. This method belongs to the non-parametric statistics and consists in obtaining, for each sample, the selected statigraph according to the experimental design. Later, the observations are exchanged between these samples. The selected statigraph is calculated again for every exchange, obtaining its corresponding distribution. Then, both calculations are compared and a decision is made. This test does not depend on the type of distribution, does not require assumptions about the structural correlation of the data and provides probability values for any number of subjects, number of points in time or number of derivations used, while controlling Type I error. This procedure makes it possible to identify with precision the effects in time and space. In our case, the statigraph used was the Student t test for dependent samples.
In the ERPs from the second session, trials with correct and incorrect responses to T2 discrimination were separately averaged in all conditions. Inverse solutions were also estimated from this session by using the VARETA model [Bosch-Bayard, Valdes-Sosa, Virues-Alba, Aubert-Vazquez, Roy-John, Harmony-Baillet, 2001].

2.2. Results and Discussion.

T1 discrimination was above 90% in all subjects, suggesting an adequate attentional status. There were no significant difference between the overall response to each configuration used in our experiment ($F(1,8)=4.49; p<0.0669$), which allows us an unbiased analysis of the rest of the data. The response to different T2 positions was not homogeneous. Those corresponding to the horizontal plane were better discriminated than the ones corresponding to the vertical plane. This effect was highly significant in the repeated measures ANOVA ($F(3,24)=99.15; p<0.0001$). But even more determinant was the interaction between configuration type and T2 positions ($F(3,24)=24.30; p<0.0001$) (Fig. 2). When T2 was presented in the same object as T1, there is observed an enhancement in T2 discrimination. In contrast, in trials where T1 and T2 were displayed in different objects all subjects were significantly less accurate, leading to an attentional blink effect.

![Figure 2 Behavioural results to T2 presentations in both configurations used in four different positions.](image-url)
These results are reflected in the ERPs (Figs 3 and 4). A negative component, contralateral to T2 presentation, was elicited with a latency of 170 ms. This component exhibited a higher amplitude when T2 was displayed in the same object as T1, when compared to trials with different objects. That second situation generates an attentional blink effect due to the amplitude decrease mentioned before. In trials with T2 on the right side there were significant differences between same and different object conditions from 560 to 650 (referenced to T1) (Fig. 5). In trials with T2 on left those differences were detected between 590 and 620 ms (referenced to T1) (Fig. 6).
Figure 4. Electrophysiological response in four electrodes (T5, T6, O1, O2) elicited by T2 on the left.

Figure 5. Permutations test for the four derivations (T5, T6, O1, O2), with T2 on the right. There were significant differences in the interval between 560 and 650 ms among the conditions for transition in a single object and transition between different objects.
Figure 6. Permutations test for the four derivations (T5, T6, O1, O2), with T2 on the left. There were significant differences in the interval between 590 and 620 ms among the conditions for transition in a single object and transition between different objects.

Figure 7. ERPs elicited by T2 on the left and right, on the electrodes 114 and 115 of the high-density montage.
In the high density recordings there was observed a negative component, contralateral to T2 presentation and similar to the one seen before (Fig. 7). This N230 component exhibited a higher amplitude in trials with same object T1-to-T2 attentional transitions, than with different object transitions (p<0.01 from 170 to 265 ms referenced to T2 presentation). In addition, the ERP response in trials where T2 was correctly identified was higher when compared to trials with errors. It suggests a close link between the attentional blink and the amplitude of the ERPs. If the hypothesis about the N230 amplitude reflecting the strength of the representation of the sensory information is valid, then the attentional blink effect detected here is related to an early suppression of that information.

On the other hand, the N230 had at least three subcomponents. The earliest contribution was a large negativity, contralateral to T2 presentation, peaking in occipito-temporal derivations and located in the ascendant edge of the N230 around 145 ms for left T2 and 170 ms for right T2. Late lateral contributions in frontal derivations were also found, ipsilateral to T2 presentation. This structure is similar to the one associated to the N1 component, generated by the stimulation patterns used in previous studies of visual attention [Di Russo, Martinez, Sereno, Pitzalis y Hillyard, 2001]. All these subcomponents were affected by the attentional blink. For the earliest subcomponent, the generators were estimated in several extrastriate areas, contralateral to T2 presentation, mainly in MT. These areas also included the superior temporal girus (contralateral to T2 presentation and distributed antero-posteriorly in almost its entire extension), the calcarine cortex and the medium temporal girus (also contralateral to T2 presentation). A late subcomponent (around 245 ms after T2) was also examined. The estimated current sources were located in frontal and lateral areas (Fig. 8), including the posterior part of both the left superior and medium temporal giri, corresponding to T2 on the right hemifield and the right inferior frontal girus and insula, corresponding to T2 on the left hemifield.
Figure 8. Current sources for the scalp distributions of the attentional effect on the early and late N230 subcomponents, as estimated by the VARETA method, projected on an average brain (glass brain model) showing the following views: coronal (left), axial (center) and sagittal (right). The estimated current density at each unitary source is represented as a percentage of the magnitude of the voxel with the largest response (values lower than 50% are not shown).

3. Experiment 2
This experiment was conceived to cancel the inclusion of the stimuli with respect to the base figures. The goal was to separate both elements for eliminating the response enhancement or same-object advantage observed in experiment 1.

3.1. Materials and Methods

Participants

Fourteen colleagues from the Cuban Center for Neuroscience and the Faculty of Biology, University of Havana took part in the experiment. All were right handed, with normal or corrected-to-normal vision and had no history of neurological or psychiatric disorders.

Procedure

All subjects were instructed to attend to the pair of base figures (similar to the ones used in the experiment 1 but without the rhombi). They were asked to fixate their gaze on a central square located in the same position of the central rhombus of experiment 1. The experiment included two configurations (ellipse on the left, horseshoe on the right and ellipse on the right, horseshoe on the left). We used the rapid introduction of a blue diamond of 7 pixels of size with a truncated corner (the diamond was embedded in a white square of 19 pixels of size, so that the diamond on top had the same spatial location of that experiment 1), first in the central position of such experiment (T1) and then in any of the other four positions, in a random order (T2). The subjects had to report the position of the truncated corner in both stimuli by using the arrow keys of the computer’s keyboard.

The psychophysiological data were re-codified and analyzed using the software STATISTICA 98 (version kernel 5.1) taking into account only T2 answers preceded by correct T1 answers. A repeated-measures ANOVA was then applied for evaluating three effects: experiment (including data from experiment 1 and 2), configuration type and T2 position.

3.2. Results and Discussion

T1 discrimination was above 90% in all subjects, suggesting an adequate attentional status. The differences between T2 positions persisted in the subject’s discrimination. The horizontal positions (left and right) exhibited a better performance compared to the vertical ones ($F(3,63)=115,12; \ p<0,0001$), despite our change in design to segregate the rhombi from base figures. It suggests that this horizontal enhancement of the attentional transitions is solid. Nevertheless, the interaction between both experimental designs and T2 positions was significant ($F(3,63)=17,09; \ p<0,001$). Particularly, T2 accuracy was leveled in experiment 2 (Fig. 9). In this second experiment, T2 response is more homogeneous across positions (Fig. 10). In addition, a significant interaction between experimental design, stimuli configurations and T2 positions ($F(3,63)=3.34; \ p<0.0246$), suggests a dependence from the stimulus configuration on the subject’s accuracy for discriminating T2. On the other hand,
when targets are segregated from base figures, the difference between same-object and different-object attentional transitions observed in experiment 1 were attenuated.

Figure 9. Interaction between the experimental groups and the T2 positions. Note that the experiment 2 exhibit a “flatter” plot compared with the experiment 1.
4. General Discussion.

The N230 amplitude decreased as a consequence of the object-based attentional blink effect, originally described as an attribute of the spatial attention [Hillyard and Anllo-Vento, 1998]. Thus, the neural processes reflected in these ERPs are not only determined by local stimulation, but by more global properties of a visual scene, such as object perceptual organization. In addition, there is a close correspondence with the behavioral results. The localization of the current sources of the N230 waveform in the early extrastriate cortex suggests an early suppression of the sensory information during attentional blink [Valdés-Sosa et. al., 2003].

In our study the comparison between experiments 1 and 2 is extremely relevant. In the second experiment, the stimuli have been designed for being segregated from the base figures. On the contrary, in the first experiment all the stimuli are part (holes) of the base figures. This integration is achieved by a surface integration process, in which there is a perceptual (color-based) match between these rhombi and the background, resulting in its perception as holes. This happens even when their representations in the subject’s retinas is spatially separated. Thus, these holes could be processed according to the attentional dynamics described by the Integrated Competition theory [Duncan, 1996]. In experiment 2, our stimuli don’t match with the background (blue vs. black), and they are probably dealt with as independent objects, dissociated from the base figures. It entails the attenuation of the inhibition/enhancement attentional effect generated by the perceptual organization of the base figures.
Therefore, the contrast between both experiments evinces de dependence of the attentional blink from the object’s perceptual organization in a given visual scene. If the subject’s attention must shift between events located in different objects there is obtained a decrease in performance. Moreover, it causes a suppression of the electrophysiological response elicited by those events. Its temporal and anatomical localization suggests that this effect appears at an early stage of the visual processing.

5. References.