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P3a and P3b components associated to the neurocognitive evaluation of invalidly cued targets

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Abstract

The present report focuses on evaluating the neurocognitive consequences of the correct or incorrect spatial prediction induced by a spatial cue. Positions in the vertical meridian were cued in order to evaluate the cognitive consequences in the processing of the validly (VC) or invalidly cued (IC) targets. The behavioural responses and the 64 EEG channel were recorded. The late endogenous event-related potential (ERP) induced by target stimuli in VC and IC targets were compared in voltage amplitude, voltage and current source density topographies. The P3a and a late positive complex, possibly P3b were increased in a statistically significant manner in the IC targets with regard to the VC targets. The previous result suggests that subjects prepare to accomplish the task upon specification of the cue, and when the IC target appeared it is treated as a low probability stimulus in a similar manner to deviant stimuli in odd-ball paradigms.

Keywords: Spatial cueing; P3a; P3b; Trial evaluation; Invalid cues; Subjective probability

The preparation for an imperative stimulus (the S2) induced by a warning stimulus (S1) generates the contingent negative variation (CNV) [21]. During the late period of the CNV, it is possible to observe task-specific preparatory activation of the motor and sensory areas that would be potentially needed to complete the task upon the information conveyed by the S1. Moreover, it is also possible to observe the activation of fronto-medial and fronto-parietal areas, which probably sustain the attentional endogenous effort during the CNV period [2,10,12–14]. The sensory-motor preparation is specific for the required response and sensory modality. A consequence of the task-specific preparation indexed by CNV is that the prepared neural set can be correct or incorrect, depending on whether the S1 represents the characteristics of the S2 validly or invalidly. This fact is clearly demonstrated in the central cue Posner paradigm, in which the central cue can validly (VC trials) or invalidly (IC trials) indicate the spatial position of the upcoming target. In case that the cue is a valid predictor of the target, there is benefit in RTs with respect to neutral cues. However, if the target is incorrectly cued, a cost occurs in the RT with respect to neutral cues [20]. Part of this effect is due to the preparation of the incorrect response for invalidly cued target stimuli [8,13].

The spatial cueing effects on the attentional sensory processing have been previously evaluated by analyzing the modulation of the ERPs to valid and invalid cues [8,16,18,19]. The general result obtained was an increase of the P1 and N1 and a decrease of posterior P3 components in valid cued trials with respect to invalid ones. The P1 component is the earliest ERP component modulated by attention and it is considered to reflect the cost to pay attention to unattended locations [1,3,13,15–17,23]. The increase of the N1 component reflects not only the benefit to pay attention to attended locations, but also the starting of discriminative processes, which are increased at the spatially attended locations. The CNV, occurring previously to the arrival of the S2, is probably the neural mechanism promoting the increased processing at attended locations [12–14]. Regarding the P3 component a delay in the IC with respect to VC trials and to non-cue conditions have been described, suggesting a delay in the processing time of the IC stimulus [18]. An increase in posterior positive components for IC with respect to VC conditions at

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the time latency of the P3 component has also been described [8,16]. The increase in the late positivity has been suggested to indicate that subjective expectancy induced by the cue [16] was not accomplished in IC trials. Furthermore, the possibility of dissociating a frontal late positive component from the posterior positive component has been observed [8] but not further explored. The absence of P3 increase has also been reported, but in an experimental conditions which differs from the previous studies in the difficulty of the task, the time interval between the S1 and the S2 and in the number of trials in which a response was required (only a 25%) [23].

The main objective of present report would be to identify some possible post-target medium and long-latency ERPs indexing the consequences of presenting central cues that correctly or incorrectly predict the position of the target. The early P1 and N1 will not be the focus of present report because vertical targets lying in left and right visual hemifield (and hemispheres) were used and no attentional modulation of these components is expected. Furthermore, the positive modulation of P1 and N1 components by valid and invalid cued locations is well described in the literature [3,15–17,23]. The specific objectives will be (i) to test the possible novelty-like treatment of IC targets indexed by the presence of a P3a component; (ii) to test if context updating in working memory is higher in the invalid than in the valid conditions, by analyzing the P3b component. The two previous components (P3a and P3b) would confirm if the invalid expectancies induced by the cue generate the same kind of components that rare stimuli generate in oddball tasks.

Fourteen subjects (9 females and 5 males, 10 right-handed) between 21 and 36 years old (mean 24.5) took part in the experiment. The experiments were conducted with the informed and written consent of each subject following the rules of the Helsinki Convention.

The stimulus presentation was computer-controlled (EEVOKE, ANT). Participants were seated 60 cm in front of a computer screen. They were instructed to fix their eyes on a white square in the center of the screen. The white spot was on during the whole experiment in order to keep the central fixation. The complete trial period included a central directional cue that was on 200 ms, and then, an attentive wait period lasting randomly between 1800 and 2000 ms (Fig. 1). The reason of choosing a variable attentive period was to focus the attentional resources of subjects on the spatial dimension rather than on the temporal dimension. Finally, a peripheral target subtending a visual angle of 0.91° and situated 8.3° eccentrically in the vertical meridian appeared (Fig. 1). Given that the directional central cue could indicate the correct or the incorrect direction in which the target would appear, two different conditions arose: validly cued targets (VC) (82% of trials) and invalidly cued targets (IC) (18% of trials). If the probability of a target to appear in the upper or the lower hemifield is computed independently of the type of trial in which it is inserted, then the targets appear randomly with a probability of 0.5 in the upper or lower hemifield. The latter probability will be considered as the objective probability of a target to appear in the upper or lower hemifield, in opposition to a subjective probability that is induced by the central cue.

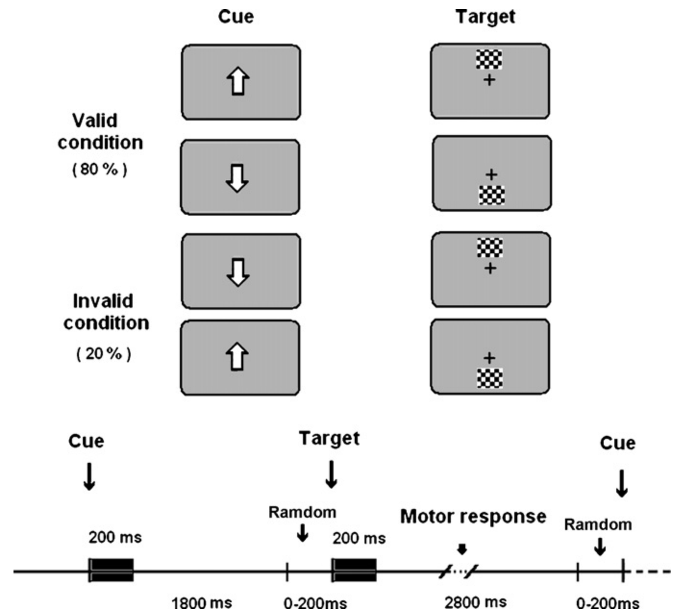

Fig. 1. Experimental paradigm. Validly and invalidly cued targets were presented (upper part of the figure) following the temporal sequence showed in the lower part of the figure.

The subjects used the right hand to respond to the targets by pressing a joystick button. They used the index finger to respond to the targets presented in the upper visual field and the thumb to respond to the targets presented in the lower visual hemifield. The intertrial intervals were randomly selected between 2800 and 3000 ms. Subjects were presented with a total of 240 trials. There were no training trials.

The RTs and the number of errors of the responses were measured for valid trials preceded by valid trials (VC–VC), valid trials preceded by invalid trials (IC–VC) and invalid trials (IC). An ANOVA analysis with two factors was applied to RTs and error analysis. The first factor was the type of trial (three levels: VC–VC, IC–VC and IC) and the second factor was the position of the target (up and down). The Bonferroni test was used as post hoc test.

The EEG was recorded from 64 scalp sites of an extended version of the International 10–20 system, using tin electrodes mounted in an electrode cap (electrocap). All the electrodes were referred to the left mastoid. Impedance was maintained below 5000 Ω. Data were recorded in DC, the amplification gain was 20,000 (ANT amplifiers). They were acquired at a sampling rate of 512 Hz, using a commercial AD acquisition and analysis board (ANT). Recordings were averaged off-line using an artifact-rejection protocol based on voltage amplitude. All the epochs for which the EEG exceeded 100 μV in any channel were automatically discarded. Seventy-five percent of invalid trials and 70.7% of valid trials were accepted for the analysis.

ERPs were obtained for each subject by averaging the EEG, using the switching on of the target as a trigger. The baseline was the interval 200–0 ms before target stimulus. The algebraically linked mastoids were computed off-line and used as reference for analysis purposes. Eye movements and blinks were monitored using the electrodes installed in the 64 channel cap, once careful