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Event related potentials changes associated with the processing of auditory valid and invalid targets as a function of previous trial validity in a Posner's paradigm

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ABSTRACT

The present study tries to analyze the neural basis of the so-called "Inter-trial Validity–Invalidity Effects" by means of Event-Related Potentials. The N1, P2, P3a and P3b components were examined. The aim is to show the sequential effects on Event-Related Potentials by analyzing the effect of previous trial condition (n – 1) in the processing of current trial target (n). Event-Related Potentials results indicate that the N1 and P2 components show higher negativity in valid trials preceded by invalid trials with respect to valid trials preceded by valid trials, elicited by the so-called "Processing Negativity". Next, the P3a and P3b components show increased positivity in invalid trials preceded by valid trials compared to invalid trials preceded by invalid trials. Present results suggest that there is a dynamic updating of attentional resources and working memory, due to the influence of previous trial condition (n – 1) on the current trial processing (n). This dynamic updating would be higher after trial validity changes, and it would be compatible with the Bayesian Brain Model.

1. Introduction

In Central Cue Posner's Paradigm (CCPP) (Posner, 1980), the central cue (S1) may validly or invalidly indicate the spatial location of the upcoming target (S2). Based on this, faster and more accurate responses have been found when the cue direction matches the target location (valid trials) than when they are discordant (invalid trials) (Arjona and Gómez, 2013). This effect has been called the "Validity Effect", and it refers to the cost produced by rearranging attentional resources from the opposite side to the one indicated by the cue (Posner, 1980; Posner et al., 1982; Jonides, 1983; Riggio and Kirsner, 1997). The so-called "Inter-trial Validity–Invalidity Effect" (Arjona and Gómez, 2011, 2013; Jongen and Smulders, 2007; Gómez et al., 2009; Arjona et al., 2014) would also appear in CCPP. This effect reflects the influence that the assessment of the validity/invalidity in one particular trial (n – 1) has on the next trial performance (n).

Different auditory studies have shown that attended stimuli elicit an enhanced N1 component, compared to unattended stimuli (Arjona and Gómez, 2013; Parasuraman, 1980; Hillyard et al., 1973; Woldorff and Hillyard, 1991; Woldorff et al., 1993; Fabiani et al., 2000). There is also a fronto-central negative shift, the so-called "Processing Negativity" (PN) (Näätänen et al., 1978; Näätänen and Michie, 1979; Hansen and Hillyard, 1980; Alho et al., 1987), which increases as a result of processing attended stimuli. Some studies mention the influence of the PN, not only in N1, but also in the P2 component (Näätänen and Michie, 1979; Michie et al., 1990).

On the other hand, invalid trials trigger an increase in P3a and P3b components, reflecting the assessment of the incorrect cue information and the updating of the cue-target conditional probability (Gómez and Flores, 2011; Mangun and Hillyard, 1991; Eimer, 1993; Gómez et al., 2008). The increase of P3b amplitude in invalid trials with respect to valid trials would be a function of the cue validity probability, suggesting that P3b indexes the difference between the spatial prediction induced by the cue and the current location of the target (Arjona and Gómez, 2016). The fact that these components are related to beliefs updating and predictive surprise has also been proposed in experiments in which the subjects have to

Abreviations: CCPP, Central Cue Posner's Paradigm; PN, Processing Negativity; EOG, electrooculography; EMG, electromyography; ERPs, Event-Related Potentials; RTs, Reaction Times; VV, valid–valid; IV, invalid–valid; II, invalid–invalid; VI, valid–invalid.

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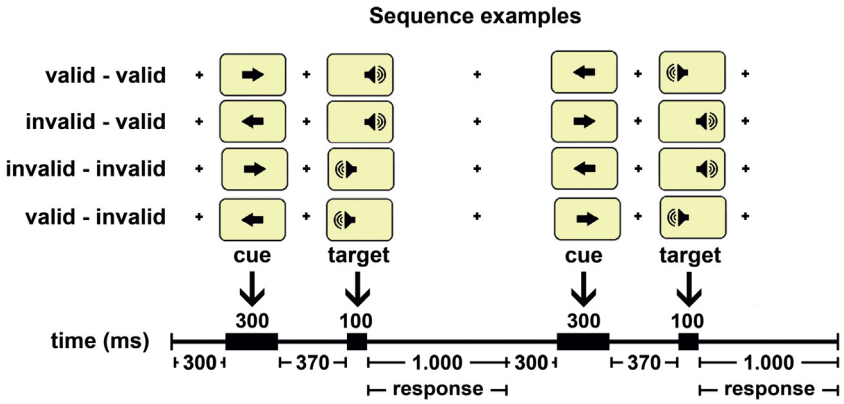

Fig. 1. Experimental paradigm.
Representation of the one-trial and two-trial structure for the different types of dyads in the experiment. The temporal sequence of stimulus presentation appears in the lower part of the figure. The central arrow (cue) was presented in the center of the screen, and the auditory stimulus (target) was presented monaurally.

infer the type of urn from which balls are extracted (Kolossa et al., 2015; Seer et al., 2016). One last interpretation is related to the predictive coding hypothesis (Friston, 2009) and, in the context of present experiment, implies that subjects would generate *a priori* conditional probabilities for the different cues (S1) as predictors of upcoming events (S2). They would also change these conditional probabilities (p (S2/S1)) based on the outcome of current trial, and so the behavior would continually adapt to the environment (Friston, 2009; Bruce and Tsotsos, 2009; Reynolds and Heeger, 2009; Feldman and Friston, 2010; Gómez and Flores, 2011). It is important to mention that the model proposed by Friston (2009), known as the 'Bayesian Brain Model', proposes that the brain operates based on a similar dynamic to Bayesian Statistics. In this context, the concept of 'Prediction Error' arises as the signal that causes the change in these probabilities, which would correspond, at the neural level, to changes in synaptic weights (Friston, 2009; Kopp, 2008; Gómez et al., 2008; Feldman and Friston, 2010; Gómez and Flores, 2011).

Based on previous results, four hypotheses can be proposed for the auditory target processing in the second trial of a two trials sequence. These four hypotheses are: (i) a higher PN will be obtained in the IV sequence, compared to the VV sequence, given that, in both sequences, the second target is attended to, but the IV sequence needs extra attentional effort (due to the lower credibility of the cue after an invalid trial) in the processes of orientation and perception of the auditory target; (ii) an increased PN will emerge in the VI sequence, compared to the II sequence, due to the greater effort needed to process the invalidly cued target after a valid trial because the attention deployed on the wrong side (indicated by the cue) will be higher in the invalid trial preceded by a valid trial than in the invalid trial preceded by another invalid trial; (iii) an increase in the P3a and P3b amplitude will be observed in the IV sequence, compared to the VV sequence, due to the higher processing of the unexpected valid target after an invalid one; (iv) an increase in the P3a and P3b amplitude will be observed in the VI sequence, compared to the II sequence, due to the higher processing of the unexpected invalid target after a valid one.

The present report complements previously published reports. Each of our previous publications corresponds to different insights (behavioral and neural responses (Jongen and Smulders, 2007)) of the sequential effects in the CCPP: (i) behavioral effects (Reaction Times, Anticipations, Incorrect responses, and Total errors) in the last trial of two-trial and three-trial sequences (Arjona and Gómez, 2011); (ii) ERPs (Contingent Negative Variation (CNV), N1, P2, P3a and P3b) in valid and invalid trials (Arjona and Gómez, 2013); (iii) Pre-target ERPs (Early Directing Attention Negativity (EDAN), CNV and Lateralized Readiness Potential (LRP)) in the second trial of two-trial sequences (Arjona and Gómez, 2013; Arjona et al., 2014). The present paper concludes the study by analyzing the post-target ERPs (N1, P2, P3a and P3b) in the second trial of two-trial sequences. Therefore, the novelty would be to understand how the processing of a target is modulated by the outcome of the previous trial.

2. Material and methods

2.1. Subjects

Thirty-four subjects participated in the experiment, but only 29 subjects (16 females; 13 males) between 19 and 35 years of age (mean: 24 years old; SD: 2.87) were fully analyzed. Five subjects with a high number of EMGs, eye movements, blink artifacts and trend derived contaminations in the EEG were excluded from the analysis. The experiments were conducted with the informed and written consent of each subject, following the rules of the Helsinki Convention. The Ethics Committee of the University of Seville approved the study.

2.2. Stimuli and behavioral paradigm

Participants were seated 60 cm from a computer screen. The subjects participated in a modified version of the CCPP, in which the central cues were arrows appearing in the center of the screen, followed by monoaural auditory stimulation (Fig. 1). The central arrow stimulus was considered the spatial orientation cue (S1), and the monoaural auditory stimulus was the imperative one (S2). The auditory stimuli were delivered to the subject's ears through headphones. Participants were instructed to fixate their eyes on a white cross in the center of the screen and pay attention to the ear indicated by the central arrow. They then had to press the right button as quickly as possible if the auditory stimulus appeared in the right ear, or press the left button if the auditory stimulus appeared in the left ear (with the index finger of the compatible hand). The response device was the Cedrus model RB-530. The auditory stimulus (1000 Hz) was randomly presented to the left or right ear with equal probability (.5). The stimulus had an intensity of 89 dB.

Each subject was presented with a total of 500 trials divided into five blocks. The central arrow (S1) had directional information: in half of the trials it pointed to the right, and in the other half to the left. In 80% of the trials the central arrow gave correct information about the target location (V: valid trials), and in 20% of the trials the central arrow pointed to the ear opposite to where the auditory stimulus would appear (I: invalid trials). Subjects were