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Temporal preparation, response inhibition and impulsivity

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ABSTRACT

Temporal preparation and impulsivity involve overlapping neural structures (prefrontal cortex) and cognitive functions (response inhibition and time perception), however, their interrelations had not been investigated. We studied such interrelations by comparing the performance of groups with low vs. high non-clinical trait impulsivity during a temporal preparation go no-go task. This task measured, in less than 10 min, how response inhibition was influenced both by temporal orienting of attention (guided by predictive temporal cues) and by sequential effects (produced by repetition/alternation of the duration of preparatory intervals in consecutive trials). The results showed that sequential effects produced dissociable patterns of temporal preparation as a function of impulsivity. Sequential effects facilitated both response speed (reaction times – RTs – to the go condition) and response inhibition (false alarms to the no-go condition) selectively in the low impulsivity group. In the high impulsivity group, in contrast, sequential effects only improved RTs but not response inhibition. We concluded that both excitatory and inhibitory processing may be enhanced concurrently by sequential effects, which enables the temporal preparation of fast and controlled responses. Impulsivity could hence be related to less efficient temporal preparation of that inhibitory processing.

1. Introduction

Regular changes in the environment afford the anticipation and preparation of efficient behavioural responses to forthcoming events. Response preparation is a transient process, which requires several tens of milliseconds to develop and decays shortly after reaching a maximum (Bertelson, 1967). However, the time course of the optimal state of preparation can be flexibly adjusted to coincide with the moment at which a task-relevant event (target) is expected to occur. This adjustment is generally called "temporal preparation" and its consequences are revealed by improvements in task performance.

Temporal preparation can be controlled voluntarily, "temporal orienting of attention" (Coull & Nobre, 1998), if individuals are provided with explicit and predictive temporal information about when a target is going to appear after a preparatory interval (e.g., early: after 400 ms, or late: after 1400 ms; see Correa (2010), for a review). Temporal preparation can also be driven by previous experiences of response preparation (Los & Van den Heuvel, 2001), which is known as "sequential effects". For example, response preparation for a target appearing after a short (400 ms) preparatory interval is stronger when that interval involves a repetition of a previous short interval rather than a switch from a previous long (1400 ms) interval, even when the sequence of short and long preparatory intervals is completely unpredictable (Woodrow, 1914).

These two mechanisms of temporal preparation have been dissociated in both behavioural and electrophysiological research (Correa, Lupiáñez, Milliken, & Tudela, 2004; Los & Heslenfeld, 2005). In a recent neuropsychological study we have reported a selective impairment in temporal orienting but not in sequential effects as a consequence of lesions in the right prefrontal cortex (Triviño, Correa, Arnedo, & Lupiáñez, 2010). The involvement of the prefrontal cortex is important here because clinical and non-clinical impulsive individuals show anatomical and physiological differences as compared to control participants in this brain area (see Brennan and Arnsten (2008), for a review; Matsuo et al., 2009).

Impulsivity is a personality trait that has been defined as "a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individuals or to others" (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001). In experimental contexts of clinical impulsivity (e.g., attention deficit and hyperactivity disorder, ADHD), impulsivity can be operationalised in terms of a behavioural deficit in response inhibition tasks (Casey et al., 1997). Thus, the common role of the prefrontal cortex in both

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temporal preparation and impulsivity suggests a close interrelation between these two constructs. However, to our knowledge, this relationship had not been considered or tested so far.

Temporal preparation and impulsivity additionally share cognitive processes, such as response inhibition and time perception. Response inhibition is influenced by impulsivity, as subjects with high trait impulsivity as measured by personality questionnaires have difficulties to inhibit a prepotent response in the stop-signal task (Logan, Schachar, & Tannock, 1997); likewise, inhibitory processes may play a role during temporal preparation (e.g., controlling excitatory neural activity, Correa & Nobre, 2008; Davranche et al., 2007). Time perception is also influenced by impulsivity, which could contribute to the inability to wait for appropriate moments that is characteristic of this clinical disorder (see Wittmann and Paulus (2008), for a review); likewise, accurate time perception is a requisite for temporal preparation (Klemmer, 1956).

The functional overlapping between response inhibition and time perception is not surprising given the common involvement of the prefrontal cortex in both cognitive processes (Coull, Vidal, Nazarian, & Macar, 2004; Harrington, Haaland, & Knight, 1998; Narayanan, Horst, & Laubach, 2006; Rubia, Smith, Brammer, & Taylor, 2003). This led us to hypothesise that impulsivity, which shares such prefrontal functions, may influence temporal preparation. Although interactions between impulsivity and temporal preparation should be most evident under clinical conditions of impulsivity, we still expected to find differences in behavioural performance during temporal preparation tasks as a function of trait impulsivity according to previous research showing behavioural and brain differences in non-clinical samples (Logan et al., 1997; Matsuo et al., 2009).

The current experiment tested this hypothesis by comparing both temporal orienting (temporal cue validity effects) and sequential effects (duration of previous preparatory interval × current interval interaction) in non-clinical participants with high vs. low impulsivity traits. We expected that temporal orienting but not sequential effects would be influenced by impulsivity, according to Triviño et al.'s findings (2010) in prefrontal patients. The use of a response inhibition go no-go task (presented on each trial after the preparatory interval), and the inclusion of a temporal estimation task (presented in the middle and at the end of the experiment), further enabled us to test whether response inhibition and time perception varied with trait impulsivity. If so, we should find both less efficient response inhibition during the go no-go task and a larger perceptual bias in the temporal estimation task in the high impulsivity group as compared to the low impulsivity group.

From a rather pragmatic perspective, an important aim of this experiment was to develop a shortened version of the task that was appropriate for diagnosing temporal preparation skills. That is, we tested whether this novel task could measure temporal orienting and sequential effects as reliably as previous versions (Correa, Lupiáñez, & Tudela, 2006; Triviño et al., 2010) in less than 10 min.

2. Methods

2.1. Participants

A sample of 33 students from the University of Granada voluntarily completed the adolescent Spanish version of the Barrat Impulsivity Scale (see Section 2.2). Twenty-six participants (mean age: 22.7 years, SD: 5.6) whose scores in the questionnaire were either below the 35% or above the 65% in our sample distribution were included in the study and respectively assigned to groups of low impulsivity (3 males, 10 females) and high impulsivity (2 males, 11 females). Data from one participant of the high impulsivity group with 65% of false alarms (which was clearly above 5 SD from the mean: 13%, SD: 1%) were excluded from the analyses. The experiment was conducted according to the ethical standards of the 1964 Declaration of Helsinki.

2.2. Apparatus and stimulus

Trait impulsivity was measured with a version of the Barratt Impulsiveness Scale 11 (Patton, Stanford, & Barratt, 1995). Since some items of the adult version could not be easily applied to our university sample (e.g., "I change jobs" or "I change residences"), we rather used the adolescent version, which has been validated in subjects up to 19 years old (BIS-11-A, Fossati, Barratt, Acquarini, & Di Ceglie, 2002). The translation of this questionnaire to Spanish was based on the work by Cosi, Vigil-Colet, Canals, and Lorenzo-Seva (2008), in which two Italian linguists translated and back translated the BIS-11-A from Italian to Spanish. The number of items and the scoring procedure were similar to the classic BIS-11 scale.

The E-prime software was used to control the experiment (Schneider, Eschman, & Zuccolotto, 2002). The task stimuli and procedure were very similar to those used in our previous experiments (e.g., Correa et al., 2006), with the main difference that the task was shortened considerably with the aim of testing a version of quick administration. All the stimuli were presented at the centre of the computer screen over a black background. The fixation point consisted of a dark grey square (0.25° × 0.25° of visual angle at a viewing distance of 60 cm). The temporal cue was either a short bar (0.38° × 0.95°) or a long bar (0.38° × 2.1°). The short bar indicated that the target would appear early (after 400 ms), and the long one that the target would appear late (after 1400 ms). The go target (0.38° × 0.76°) was either the letter 'O', or the letter 'X', whereas the no-go target was the digit '8'. The no-go target thus shared perceptual features with the two go targets. There were 25% of trials that included the no-go target. In the go condition, participants pressed the 'B' key whenever an 'O' or an 'X' appeared. In the no-go condition, participants should inhibit responding, otherwise they were provided with feedback showing the word "incorrect" for 500 ms and a 2000-Hz auditory tone of 50 ms.

2.3. Procedure

Participants were seated at a viewing distance of about 60 cm and performed a go no-go task. They were instructed to respond as quickly as possible only to the go targets, and to avoid responding to the no-go target. Each trial began with the fixation point presented for a random interval ranging between 500 and 1500 ms. The temporal cue was then presented in red for 50 ms. Next, the screen remained blank for a variable delay of 350 or 1350 ms depending on the Stimulus Onset Asynchrony (SOA) for that trial (Fig. 1). Therefore, the SOA could be either 400 or 1400 ms. The target was displayed for 100 ms and was then replaced by a blank screen until the participant made a response or for a maximum

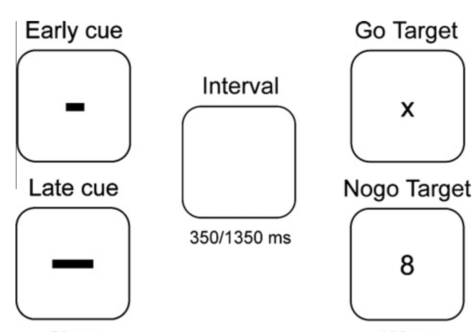

Fig. 1. Schematic of the task design and main events of a trial.