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Research Report

Comparative analysis of event-related potentials during Go/NoGo and CPT: Decomposition of electrophysiological markers of response inhibition and sustained attention

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ABSTRACT

Neuropsychological tests target specific cognitive functions; however, numerous cognitive subcomponents are involved in each test. The aim of this study was to decompose the components of two frontal executive function tests, Go/NoGo (GNG) and cued continuous performance task (CPT), by analyzing event-related potentials (ERPs) of 24 subjects both in time and time-frequency domains. In the time domain, P1, N1, P2, N2 and P3 peak amplitudes and latencies and mean amplitudes of 100 ms time windows of the post-P3 time period were measured. For GNG, the N1 amplitude and for both GNG and CPT N2 amplitudes were significantly higher in the NoGo condition compared with the Go condition. P3 had a central maximum in the NoGo conditions of both paradigms in contrast to a parietal maximum in the Go conditions. All peaks except P1 and mean amplitudes of the post-P3 period were more positive in CPT compared to those of GNG. N1, N2 and P3 latencies were longer for the NoGo condition than the Go condition in the CPT. In time-frequency analyses, the NoGo condition evoked higher theta coefficients than the Go condition, whereas the CPT and GNG paradigms differed mainly in the delta band. These results suggest that theta component reflects response inhibition in both GNG and CPT, whereas delta component reflects the more demanding sustained attention requirement of the CPT. The latency prolongation observed with the NoGo condition of the CPT paradigm was thought to be due to perseverance/inhibition conflict enhanced by the primer stimuli in CPT.

1. Introduction

Go/NoGo (GNG) and continuous performance task (CPT) are two neuropsychological tests that are designed to measure complex attentional functions such as response inhibition and sustained attention, which are thought to be mediated by the prefrontal cortex (Weintraub, 2000). Sustained attention is defined as the ability to maintain an efficient level of responding on a demanding task over a period of time (Ward, 2004). CPT is used to measure sustained attention but is also sensitive to response inhibition and has been used for the assessment of numerous clinical entities such as attention

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deficit disorder, schizophrenia and depression (Ballard, 1996; Gonzalez-Garrido et al., 2001; van Leeuwen et al., 1998; Zillessen et al., 2001), whereas GNG paradigm is a purer test of response inhibition (Weintraub, 2000) and has been especially used for disorders such as neurological conditions involving orbito-frontal cortex and depression (Kaiser et al., 2003; Leimkuhler and Mesulam, 1985).

The GNG paradigm consists of a series of two different stimuli, where generally the probabilities of the Go and NoGo stimuli are equal. The simple CPT paradigm has a similar design, where however a relatively small number of Go stimuli are presented within a large set of varying distractor stimuli that correspond to the NoGo condition. The complex cued version of the CPT further includes a primer stimulus, which is followed either by the Go stimulus that has to be responded to as fast as possible or any distractor corresponding to the NoGo condition. Any other stimulus that does not follow the primer is a meaningless distractor.

The presence of a large set of interspersed distractors in the cued CPT paradigm makes it more complicated for the subject to focus his/her attention on the Go and NoGo stimuli, hence builds a higher demand of sustained attention compared with the GNG paradigm (Weintraub, 2000). A higher level of vigilance is also needed because the accurate performance depends on both the accurate representation of the primer and the maintenance of this information during the delay period (Dias et al., 2003). Additionally, although the Go and NoGo stimuli have equal probabilities in both the GNG and CPT paradigms, we assume that the presentation of the primer stimulus generates a bias for a coming Go stimulus and a preparation for a fast motor response. Such bias produced by the primer of the cued CPT paradigm should create a difficulty for the subject to resist to respond and to enhance the trend for perseverance to the motor task.

Electrophysiological correlates of the abovementioned cognitive domains have been analyzed using event-related potential (ERP) studies based on various experimental paradigms. One of the most studied ERP measures, the P3, is typically obtained with an oddball paradigm as a positive going potential that peaks approximately 300 ms after stimulus onset with a parietal maximum, and is commonly thought to reflect the amount of attentional resources directed to the task-relevant stimulus (Donchin and Coles, 1988; Polich, 1999; Polich and Kok, 1995).

Pfefferbaum et al. (1985) found a P3 with a maximum at Pz on Go condition and a P3 with a centro-parietal maximum for NoGo condition with a semantic GNG paradigm. While the Go P3 has the same characteristics as the oddball-P3, the NoGo P3 has a different topography, which shows that it corresponds to a distinct neuronal process. Additionally, visual GNG tasks are known to produce an enhanced fronto-central N2 wave (Falkenstein et al., 1999). N2 is a negative ERP wave with a fronto-central distribution that peaks around 250 ms after stimulus presentation and is enhanced when there is a tendency to make a prepotent but incorrect response, which is the case for both GNG or CPT tasks (Kopp et al., 1996; Nieuwenhuis et al., 2004).

In most ERP studies, the CPT task instead of a simple GNG task has been employed for the testing of Go and NoGo responses, although CPT by design is significantly more demanding on cognitive domains such as resistance to perseverance and sustained attention. The aim of this study is to determine the specific electrophysiological subcomponents corresponding to response inhibition, resistance to perseverance and sustained attention through a comparative analysis of ERPs elicited by GNG and CPT paradigms on the same subject group, under same conditions and with similar stimulus characteristics. ERPs were compared in two separate stages, where in the first stage the Go vs. NoGo responses of both paradigms were compared to obtain the signal features reflecting the response inhibition, and in a second stage, the compatible conditions of both paradigms were compared to obtain the components reflecting the sustained attention and the resistance to perseverance.

The time-frequency analysis based on Wavelet Transform (WT) has been shown to be a powerful tool for the decomposition of ERPs into functional components (Ademoglu, 1995; Ademoglu et al., 1998; Basar et al., 1999, 2001; Demiralp and Ademoglu, 2001; Demiralp et al., 1999a,b, 2001a,b; Devrim et al., 1999; Samar et al., 1995; Yordanova et al., 2000). ERPs consist not only of sequential but also parallel activations of different neuronal groups. Hence, temporally overlapping activations are necessarily involved in the ERP generation (Basar, 1980). Therefore, the analysis of the ERPs in the time domain using peak amplitudes and latencies that reflect superimposed activities of different subsystems is inefficient for detecting the parallel activations. However, different frequency characteristics of the mechanisms operating in parallel may help in the decomposition of the ERPs into functional components. Therefore, the analysis of the time-varying frequency content of the ERPs by using Wavelet Transform has revealed significant additional information that is not available in the time domain (Ademoglu, 1995; Ademoglu et al., 1997, 1998; Basar et al., 1999, 2001; Demiralp

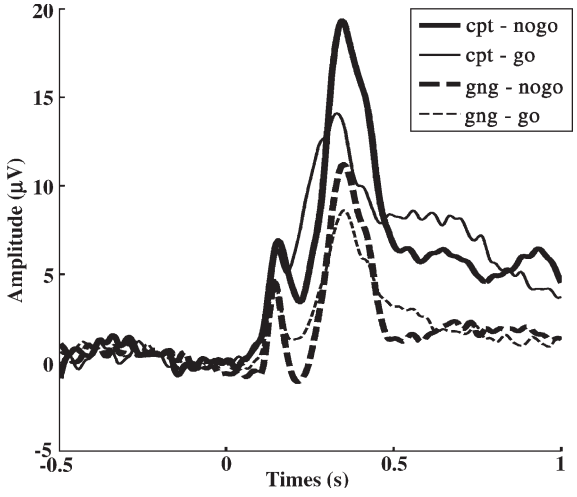

Fig. 1 – Grand averages of Go and NoGo conditions of GNG and CPT paradigms on Cz. The basic wave pattern of P1, N1, P2, N2 and P3 peaks was visible in both GNG and CPT. There was a general positive shift in CPT amplitudes, which was seen as less negative N1 and N2 amplitudes, more positive P2 and P3 amplitudes and a continuous positive shift at the post-P3 period compared to the GNG recordings.