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Design and implementation of a multi-PNN structure for discriminating one-month abstinent heroin addicts from healthy controls using the P600 component of ERP signals

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Abstract

A multi-probabilistic neural network (multi-PNN) classification structure has been designed for distinguishing one-month abstinent heroin addicts from normal controls by means of the Event-Related Potentials' P600 component, selected at 15 scalp leads, elicited under a Working Memory (WM) test. The multi-PNN structure consisted of 15 optimally designed PNN lead-classifiers feeding an end-stage PNN classifier. The multi-PNN structure classified correctly all subjects. When leads were grouped into compartments, highest accuracies were achieved at the frontal (91.7%) and left temporo-central region (86.1%). Highest single-lead precision (86.1%) was found at the P3, C5 and F3 leads. These findings indicate that cognitive function, as represented by P600 during a WM task and explored by the PNN signal processing techniques, may be involved in short-term abstinent heroin addicts. Additionally, these findings indicate that these techniques may significantly facilitate computer-aided analysis of ERPs.

Keywords: Heroin addicts; Event-related potentials (ERPs); P600 component; Pattern recognition

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1. Introduction

Event-related potentials (ERPs) are electrical potentials, usually measured on the scalp, and are distinguished for their high temporal resolution, allowing for real-time and non-invasive observation of electrical activity changes in the brain during the processing of information related to the presentation of stimuli (or events) (Fabiani et al., 2000). Late positive components of the ERP waveform, such as the P300 and the P600 components have attracted special attention in ERP research. Both components are related to working memory (WM) processes, i.e. keeping information actively in mind, the P300 being more related to the on-line updating of working memory and/or attentional operations involved in this function (Polich, 1998), while the P600, elicited between 500 and 800 ms after stimulus presentation, has been linked to hippocampal function (Guillem et al., 1998; Grunwald et al., 1999), having much in common with WM operation (Garcia-Larrea and Cezanne-Bert, 1998; Guillem et al., 1999; Frisch et al., 2003). P600 is thought to reflect the response selection stage of information processing (Falkenstein et al., 1994), i.e. the stage that 'assigns a specific response to a specific stimulus'.

The relationship between substance dependence, such as cocaine and/or heroin abuse, and neurophysiological functions has been previously addressed by various workers, using the P300 (Easton and Bauer, 1997; Martin and Siddle, 2003; Papageorgiou et al., 2003; Kouri et al., 1996; Bauer, 1997, 2002; Biggins et al., 1997; Attou et al., 2001) and, to a lesser extent to the P600 (Papageorgiou et al., 2001) concerning six-month, i.e. long-term, abstinent heroin addicts.

As far as the application of P600 component of ERPs in picking up relevant aspects of addiction, in association with neuropsychological operation, Papageorgiou et al. (2001) provided evidence indicating that abstinent heroin addicts manifest abnormal aspects of second-pass parsing processes, as reflected by the P600 latencies, elicited during a WM test.

The aim of the present study is twofold: first, to search deeper into the P600 signals by extracting new P600-signal characteristics and by employing powerful classification procedures, to develop a pattern recognition system for discriminating drug-abusers from controls. The P600 component has only been previously employed (Vasios et al., 2002) for computer-based discrimination of normal controls from patients suffering from schizophrenia. Second, to design a novel classification system, according to which composite information is collected from all fifteen leads simultaneously and is fed into a multi-classifier structure to achieve highest classification accuracies.

2. Material and methods

2.1. Subjects

Sixteen one-month abstinent heroin-abusers (4 females and 12 males), matched on age and educational level to 20 normal controls (5 females and 15 males), were examined. The former were recruited from the outpatient university clinic of Eginition Hospital of Athens, Greece. Drug abstinence was verified by urine tests. The addicts were mainly long users of heroin, they had not made prolonged use of other drugs, and had no history of mental retardation. The controls were recruited from hospital staff and local volunteer groups. All participants had no history of any neurological or hearing problems and were right-handed as assessed by the Edinburgh Inventory Test (Oldfield, 1971). Written informed consent was obtained from both patients and control subjects.

2.2. ERP generation procedure

All subjects were evaluated by a computerized version of the digit span subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1955). The examination procedure followed for each subject is detailed in a previous work by members of our research team (Papageorgiou et al., 2003; Papageorgiou and Rabavilas, 2003). ERPs were recorded using Ag/AgCl electrodes (leads), during the 1 s interval between the warning stimulus and the first administered number and were digitized at a sampling rate of 500 Hz. EEG activity was recorded from 15 scalp leads based on the Inter-