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Impulsivity, intelligence and P300 wave: An empirical study

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ABSTRACT

The aim of this study was to analyze the relationships among impulsivity, intelligence and P300, a well-known component of the event-related potential widely studied in personality and intelligence research. Eighty-two males completed the Barratt Impulsiveness Scale and the two-subtest form of the Wechsler Abbreviated Scale of Intelligence. A subsample of 45 participants (mean age=24.4, SD=4.6) performed a visual oddball task, consisting of a two-letter recognition task, during which psychophysiological data were recorded. Although no significant relationships emerged for P300 latency, overall results suggest that the P300 amplitude was positively related to IQ and negatively related to impulsivity. Those who scored high on impulsivity (high impulsives) had lower P300 amplitudes than low impulsives, but this relationship was not significant when controlling for individual differences in mental ability. The results also showed an inverse relationship between mental ability and impulsivity. That is, high impulsives demonstrated reduced cognitive performance on intelligence testing and it is reflected in their reduced P300 amplitude. These findings are likely due to high impulsives' less efficient ability to inhibit task-irrelevant information or to ignore additional information intake. It was suggested that impulsivity exerts a disadvantageous influence on the performance of tasks (such as those used on intelligence tests) in which exclusive concentration and sustained attention are necessary.

1. Introduction

The last decade has brought renewed interest for investigating the association between intelligence and personality (e.g., Ackerman and Heggestad, 1997; Austin et al., 2002; Saklofske and Zeidner, 1995; Sternberg and Ruzgis, 1994; Wolf and Ackerman, 2005; Zeidner and Matthews, 2000). When considering major personality dimensions (such as Eysenck's PEN or Big Five factors), the most consistent findings are that general cognitive ability (*g* factor) is negatively related with Neuroticism and positively with Openness to Experience; negative correlations between *g* factor and Psychoticism have emerged only in some studies (e.g., Ackerman and Heggestad, 1997; Ashton et al., 2000; Austin et al., 2002; Zeidner and Matthews, 2000). In their insightful review, Brebner and Stough (1995) indicated that "outside of the realm of intelligence testing, commonsense observations of relationships between intelligence and personality tend to be in terms of the speed or efficiency of information processing or of the carefully considered, planful behaviour […]. This should alert us to the likelihood that intelligence is only related to personality factors that reflect characteristic ways of dealing with information" (p. 322). We suggest that impulsivity should be considered one of these personality factors. In past studies, impulsivity was conceptualized as a cognitive style (Kagan, 1965) that influences reasoning ability (Baron, 1982) and moderates the relationship between scholastic abilities and performance (Kipnis and Resnick, 1971). It is plausible that some of the key features of information processing and behavior of impulsive individuals (difficulties in sustained attention, motor disinhibition, lack of planning) may modulate the efficacy of cognitive processing and can negatively affect cognitive performance during intelligence testing.

Previous studies that investigated the relationship between impulsivity and cognitive ability showed mixed results. Harmon et al. (1997) reported that youthful offenders (high impulsives) achieve lower verbal intelligence scores than controls. In a study by Corr and Kumari (1998), significant differences in fluid intelligence between high and low impulsives were observed. Impulsivity-related differences in working memory were shown in the study by Whitney et al. (2004). Schweizer (2002) demonstrated the negative influence of impulsivity on figural and numeric/alphabetical reasoning tasks. De Wit et al. (2007) found an inverse relationship between IQ and Non planning and Attentional impulsivity subdimensions of the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995). In contrast, Austin et al. (2002) did not observe a significant relationship between a general ability factor and the impulsivity scale of the Karolinska Personality Scales. No relationships were found between

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the impulsivity scale of the Personality Research Form and measures of crystallized and fluid intelligence in the study of Ashton et al. (2000).

A possible explanation for these mixed results lies in the lack of agreement regarding the definition and the measurement of the impulsivity trait (e.g., Evenden, 1999). One of the most influential theoretical models of impulsivity was developed over decades by Ernest S. Barratt (for a historical overview, see Barratt, 1993). Barratt conceptualized impulsivity as a biologically based trait and identified three second order impulsivity factors that are assessed by the BIS-11, a commonly reported trait measure of impulsivity. According to Barratt, high impulsive individuals are present oriented and do not plan their activities (Non Planning subdimension), as they are characterized by the tendency to react very quickly (Motor Impulsivity subdimension). Additionally, they tend to have difficulty maintaining sustained attention on monotonous tasks, being preferentially activated by high-stimulant and non-repetitive tasks (Attentional Impulsivity subdimension).

The aim of the present study was to evaluate the relationship between impulsivity subdimensions, as measured by the BIS-11, and the performance on the Two Subtest Form of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). A further aim of the study was to test the relationships between impulsivity, general mental ability and the P300, a well-known positive wave of the event-related potentials (ERPs) peaking at about 300 ms from stimulus onset.

The P300 is related to processes that involve classifying or updating memory representations of stimuli. Its amplitude increases as the demand for cognitive resources increases, with larger P300 amplitudes reflecting the increased attentional resources engaged or, more generally, the processing capacity employed to encode and update working memory (e.g., Polich and Kok, 1995). In addition, P300 latency is a measure of stimulus evaluation and classification time, and it is thought to be independent of the time needed for response-related processes (e.g., Coles et al., 1995; Doucet and Stelmack, 1999).

Over the last decades, several studies have investigated the relationship between personality traits and P300 (e.g., Daruna et al., 1985; De Pascalis, 2004; De Pascalis et al., 2004; De Pascalis and Speranza, 2000; Ortiz and Maojo, 1993; Polich and Martin, 1992; Pritchard, 1989, Stelmack et al., 1993), suggesting a reduced P300 amplitude in impulsive (and extraverted) subjects. Furthermore, reduced P300 amplitude was related to antisocial behaviours linked to impulsivity and to the disinhibitory processes in alcoholism and substance abuse (Bauer and Hesselbrock, 1999; Barratt et al., 1997; Carlson et al., 1999; Gerstle et al., 1998; Harmon-Jones et al., 1997; Justus et al., 2001; Mathias and Stanford, 1999; Moeller et al., 2004). The reduced P300 amplitude of impulsives was usually interpreted as reflecting a reduction in attentional resources available for the information processing, because these resources are not allocated effectively or because of a decreased physiological arousal.

The above mentioned studies indicate a consistent negative relationship of impulsivity with P300 amplitude but not with P300 latency. On the other hand, P300 latency was proposed to reflect individual differences in the speed of perceptual information processing and it was linked to human intelligence. Shorter P300 latencies were found to be associated with different measures of cognitive ability (Bazana and Stelmack, 2002; Gurrera et al., 2005; Jausovec and Jausovec, 2000; McGarry-Roberts et al., 1992; O'Donnell et al., 1992; Polich and Martin, 1992; Polich et al., 1983; Stelmack and Houlihan, 1995; for a review, see Stelmack and Beauchamp, 2001). Burns, Nettelbeck and Cooper (2000) found that the relationships between fluid and crystallized general ability factor and physiological speed, as measured by P300 latency, share 10–25% of variance. In contrast, the relationship between P300 amplitude and IQ is less clear and in need of further empirical investigation. Some past studies have failed to demonstrate a consistent relationship between P300 amplitude and cognitive abilities (e.g. Polich and Martin, 1992; for a review, see Vernon et al., 2000). On the other hand, recent studies suggest a positive relationship between P300 amplitude and the performance on intelligence tests or subtests (e.g. Bazana and Stelmack, 2002; Beauchamp and Stelmack, 2006; De Pascalis et al., in press; Gurrera et al., 2005; Katsanis et al., 1997; Portin et al., 2000).

The main goal of the present study was to examine the relationships among individual differences in mental ability, impulsivity and the P300 component. In previous studies the P300 wave was extensively analyzed in relationships with both impulsivity and mental ability, but no systematic study was conducted on the overall pattern of relationships between impulsivity, intelligence and P300. Starting from the above mentioned experimental evidence, it was anticipated that high impulsives, compared to low impulsives, would exhibit a lower performance on WASI tests and a lower P300 amplitude during the performance of a simple stimulus discrimination task. In particular, in the present study impulsivity-related differences in P300 amplitude were investigated controlling for individual differences in mental ability in order to highlight the pattern of covariation among these variables. In accordance with past literature, we hypothesized that P300 latency, a measure of stimulus evaluation and classification time, should be negatively correlated with Intelligence, while no significant relationship between impulsivity and P300 latency was expected.

2. Materials and methods

2.1. Participants and procedure

The experiment was conducted at the Department of Behavioral and Brain Sciences, University of Texas Medical Branch at Galveston, USA. The participants were 82 males between the ages of 18 and 35 years (mean=24.2, SD=4.4), selected from a pool of college students and local employees. All participants spoke English as their first language and received a monetary compensation of 100 USD for participating. The experimental session began at 8:00 a.m. All participants gave informed consent prior to their inclusion in the study, which was approved by the local ethics committee.

All participants were administered the Wechsler Abbreviated Scale of Intelligence (WASI: Wechsler, 1999) and the Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995) and other measures not relevant for the present study. A randomly selected sub-sample of 45 participants (mean age=24.4, SD=4.6), performed a single block of an oddball task, in which psychophysiological data were recorded. The sub-sample was equivalent to the total group of participants for age [$F_{1,80}$=.11; n.s.], BIS-11 total score [$F_{1,80}$=.16; n.s.] and general intelligence score [$F_{1,80}$=.22; n.s.]. The order of the assessments was pseudo-randomized across participants.

2.2. Psychophysiological recording

The EEG was recorded from 32 scalp sites while participants were seated in a comfortable chair in a dimly-lit room. However, for the present study, the recording sites of interest were Fz, Cz, and Pz, given that these scalp leads were found to be the most sensitive to individual differences in intelligence and impulsivity factors.

Participants completed a visual oddball task consisting of a two-choice letter recognition task (see Barratt et al., 1997). Subjects wore stereo headphones that emitted continuous white noise (in the 40–60 dB range) for masking extraneous sounds, and a plus sign was fixed in the centre of the computer monitor at a distance of approximately 55 cm. One-hundred and fifty visual stimuli were presented, by using a presentation time of 1 s and a stimulus onset asynchrony (SOA) of 5 s. A 1000 Hz sinusoidal tone (1-s duration) preceded the presentation of each visual stimulus. The Rare stimulus (20% of the trials) was a white 'B' (1.3 cm high × 1.5 cm wide) and the Standard stimulus (80% of the trials) was a white 'A' (same size as the Rare stimulus). Participants were asked to press a key pad with their left