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Harm avoidance is related to mismatch negativity (MMN) amplitude in healthy subjects

M. Hansenne, E. Pinto, G. Scantamburlo, B. Renard, J. Reggers, S. Fuchs, W. Pitchot, M. Ansseau

Department of Psychiatry, University of Liège, CHU Sart Tilman (B35), B-4000 Liège, Belgium

Abstract: Event-related potential (ERP) studies evidenced that some personality dimensions induced different controlled cognitive attitudes towards the processing of information. However, few data are available on the possible relationships between personality and automatic attention or early sensory processing. In the present study the relationships between the mismatch negativity (MMN) and personality described by the Cloninger model of personality were investigated. Subjects were 32 healthy volunteers. The MMN was recorded with frequent stimuli tones of 1470 Hz, 70 dB and 40 ms duration, and target (20%) tones of 1470 Hz, 70 dB, 80 ms duration. The subjects completed a French version of the 226-item self-questionnaire TCI within the day following psychophysiological recording. The results showed that the HA dimension was negatively correlated with the MMN amplitude. The association was more present among women than men. No significant relationship existed between the other dimensions of personality and either the MMN amplitude or latency. These findings suggest that the MMN is related to the behavioral inhibition system (BIS), a fact which is consistent with clinical studies conducted on schizophrenia and anxiety disorders. In conclusion, this study suggests that personality dimensions induce different automatic attitudes towards the processing of information.

Keywords: MMN; Personality; TCI; Psychophysiology

1. Introduction

Several lines of evidence have suggested that some personality dimensions modulate the P300 Event-Related Brain Potential (ERP) (for a review of P300, see Hansenne, 2000a, 2000b; Picton, 1992; Polich & Kok, 1995). Most reports have explored the relationships between P300 and the introversion-extraversion dimension of Eysenck's theory because of its putative biological bases. Indeed, Eysenck (1990) suggested that differences between introverts and extraverts are based neurophysiologically in the ascending reticular activating system of the brain, an area which modulates cortical arousal and inhibition. In this view, introverts are characterized by greater chronic cortical arousal than extraverts. A consistent result of the studies which relate P300 to this personality dimension is that introverts exhibit higher P300 amplitude than extraverts (Brocke, Tasche, & Beauducel, 1996; Daruna, Karrer, & Rosen, 1985; O'Connor, 1983; Polich & Martin, 1992). However, opposite results were described by Cahill and Polich (1992). Moreover Pritchard (1989) has found no relationship between extraversion and P300 amplitude but has demonstrated a negative relation between neuroticism and P300 latency in male subjects. Due to these inconsistent results moderating variables must be taken into account. In this context, by varying the content of stimulus complexity extraverts exhibit higher P300 amplitude in an experimental setting that induces higher levels of arousal (Brocke, Tasche, & Beauducel, 1997). Moreover, Stenberg (1994) reported that the relationship between P300 and extraversion was attributed to the impulsive subtrait of the extraversion scale. Furthermore, the duration of the experiment can explain the contradictory results: in the initial phase of the experiment, P300 amplitude was larger among extraverts (Ditraglia & Polich, 1991; Stenberg, 1994).

More recent studies have focused on the relationship between P300 and personality with the biosocial model of Cloninger (Cloninger, 1986; Cloninger, Svrakic, & Przybeck, 1993) and the big five model of personality (Digman, 1990). Hansenne (1999) reported that P300 amplitude was positively related to the novelty seeking dimension and negatively associated with the harm avoidance dimension in healthy subjects. Vedeniapin, Anokhin, Sirevaag, Rohrbaugh, and Cloninger (2001) demonstrated that P300 amplitude was positively correlated with the self-directed-ness dimension. In a limited sample of healthy subjects, P300 amplitude was positively related to extraversion, openness, agreeableness, and conscientiousness and negatively related to neuroticism (Gurrera, O'Donnell, Nestor, Gainski, & McCarley, 2001).

Overall, since P300 reflects controlled cognitive processes, these studies evidenced that some personality dimensions induced different controlled cognitive attitudes towards the processing of information. Another important aspect of information processing which could be related to personality is early sensory processing and automatic attention. Unfortunately, few data are available on the possible relationships between personality and either automatic attention or early sensory processing.

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Among the ERPs, the mismatch negativity (MMN) is considered as a neurophysiological index of early sensory processing and automatic attention, and is related to the orienting reflex (Näätänen, 1990, 1995). The MMN is a fronto-central component elicited by a physically deviant auditory stimulus occurring among frequent stimuli with a latency of about 130 ms from stimulus onset and lasting to about 250/300 ms (Näätänen, 1995, 2001; Näätänen, Gaillard, & Mantysalo, 1978; Picton, Alain, Otten, Ritter, & Achim, 2000). The deviant sounds may differ from the standard sound in pitch, duration, intensity, and spatial location. The latency of the MMN is inversely related, and its amplitude positively related, to the magnitude of the difference between the standard and the deviant stimuli (Näätänen & Gaillard, 1983).

The MMN is presumably generated by a mismatch process between the sensory input from a deviant stimulus and a short-term memory (sensory-memory) trace representing the physical features of the standard stimuli. This process appears to be automatic since the MMN is elicited even by changes in unattended auditory stimuli. Moreover, as opposed to P300, MMN seems not to be affected by the predictability of the deviant stimuli (Näätänen, 1995, 2001).

From a clinical point of view, several studies have demonstrated that MMN is impaired in patients with schizophrenia (Alain, Woods, & Knight, 1998; Catts et al., 1995; Javitt, Doneshka, Grochowski, & Ritter, 1995), and some studies have proposed that this impairment represents a deficit in inhibitory functioning probably located in frontal lobes (Alain et al., 1998; Alho, Woods, Algasi, Knight, & Näätänen, 1994). Following these authors, a dysfunction of the behavioral inhibitory system (BIS) is responsible for the reduced MMN found in schizophrenia. Concerning anxiety disorders, Towey et al. (1993) have found that obsessive compulsive disorder patients exhibited higher N200 amplitude. Moreover, Clark, McFarlane, Weber, and Battersby (1996) have demonstrated that generalized anxiety patients presented higher P3a amplitude at frontal electrode. These studies suggest that anxiety disorders are characterized by increased signs of automatic processing resulting from an increased BIS.

In the present study the relationships between the MMN and personality described by the Cloninger model of personality were investigated. The model of Cloninger is based on four temperaments (novelty seeking, harm avoidance, reward dependence, and persistence) and three characters (self-directedness, cooperativeness and self-transcendence) (Cloninger, 1986, 1987; Cloninger & Svrakic, 1997; Cloninger et al., 1993). Briefly described, novelty seeking (NS) is defined as the tendency to respond actively to novel stimuli leading to pursuit of rewards and escape from punishment. Harm avoidance (HA) corresponds to the tendency toward an inhibitory response to signals of aversive stimuli that lead to avoidance of punishment and nonreward. Reward dependence (RD) is defined as the tendency for a positive response to signals of reward to maintain or resist behavioral extinction. Persistence (P) is described in terms of perseverance despite frustration and fatigue. Self-directedness (SD) refers to the ability of an individual to control, regulate and adapt his behavior to fit the situation in accord with individually chosen goals and values. Cooperativeness (C) is formulated to account for individual differences in identification with and acceptance of other people. Self-transcendence (ST) is a characteristic associated with spirituality, and refers generally to identification with everything conceived as essential and consequential parts of a unified whole. The Temperament and Character Inventory (TCI) is a 226-item self-questionnaire developed by Cloninger and his colleagues to assess these seven dimensions of personality (Cloninger, Przybeck, Svrakic, & Wetzel, 1994).

From a theoretically point of view, the HA dimension is related to the BIS proposed by Gray (1987). BIS is defined as a behavioral inhibition system which mediates responses to conditioned signals of punishment and it may be responsible for individual differences in anxiety. In contrast, the NS dimension is related to the behavioral activation system which mediates responses to conditioned signals of reward, and it may be responsible for individual differences in impulsivity.

In Cloninger's model, temperaments and characters relate the attitudes of an individual toward environmental stimulations and are associated to some psychological factors like attention, and sensory processing. These psychological factors are also related to the MMN. Therefore, this study investigates the relationship between the MMN and the personality dimensions described by the TCI. Since temperaments reflect automatic response to experience, relationships between the MMN and dimensions are preferentially expected for temperaments. More particularly, based on the fact that the HA dimension is related to the BIS proposed by Gray (1987) and that BIS is impaired in patients with anxiety disorders and in schizophrenia where MMN is altered, relationships between HA and MMN amplitude are expected.

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2. Methods

2.1. Subjects

Thirty-two healthy subjects (14 women and 18 men, mean age of 28.9±10.5 years) recruited among the staff of the University Hospital of Liège (Belgium) participated in the study. They were paid for their participation (10.000 BEF). They all underwent a medical interview by a physician (BR) to exclude psychiatric or somatic disorders. The Ethical Committee of the University of Liège Medical School approved the protocol and all subjects gave their informed consent.

2.2. Personality assessment

The subjects completed a French version of the 226-item self-questionnaire TCI within the day following psychophysiological recording. Cloninger has approved the translated version of the TCI by Téhérani and Lépine and validated by Pélissolo and Lépine (1997) used in this study. The subjects were asked to read each item carefully and to answer all of them even if they were not completely sure of the answer. After the subjects completed the questionnaire, one author (MH) checked whether the items had all been answered. All subjects filled 'false' for the validity item (I have lied a lot on this questionnaire).

2.3. Psychophysiological recording

The MMN recording was carried out in a sound-attenuated room. The subjects were tested until a total of 150 trials was obtained after rejecting trials for eye movement or other artifacts. The auditory stimuli were presented binaurally in a random series at the rate of one trial every second. The frequent stimuli were tones of 1470 Hz, 70 dB and 40 ms duration, and the other 20% were tones of 1470 Hz, 70 dB, 80 ms duration. To be sure that the subjects were distracted from the task, they were instructed to perform arithmetic operations during the experiment. The task consisted in ordering a series of seven digits (e.g. the serie 9 6 2 0 7 4 5 must be sorted as follows: 0 2 4 5 6 7 9). All the subjects performed this secondary task without any difficulties and their performances on this task were comparable (mean value of 18.6±2.7).

The EEG was recording using silver-silver chloride electrodes attached at Fz, Cz and Pz using linked earlobes for reference and right forehead for ground. All sites were cleaned with acetone and abraded to maintain a resistance below 5 kΩ. EOG was recorded from above the left eye. Amplifier gains were set at 10,000, with a band pass of 0.05-35 Hz. The EEG was digitized at 250 sample/s for 900 ms with a 100 ms prestimulus baseline. Trials on which the EEG or EOG exceeded 50 μV were rejected automatically.

MMN amplitude and latency were measured as the difference in voltage between baseline and the higher point between 150 and 260 ms after the stimulus on the difference waves obtained by subtracting frequent tone ERPs from deviants tone ERPs.

2.4. Statistical analysis

The statistical analyses were performed using Statistica (4.5) for Windows (Statsoft, 1993). The relationships between MMN and the personality dimensions obtained by the TCI were assessed by the nonparametric Kendall Tau correlation coefficients. Gender differences were assessed by the Mann-Whitney *U* test.

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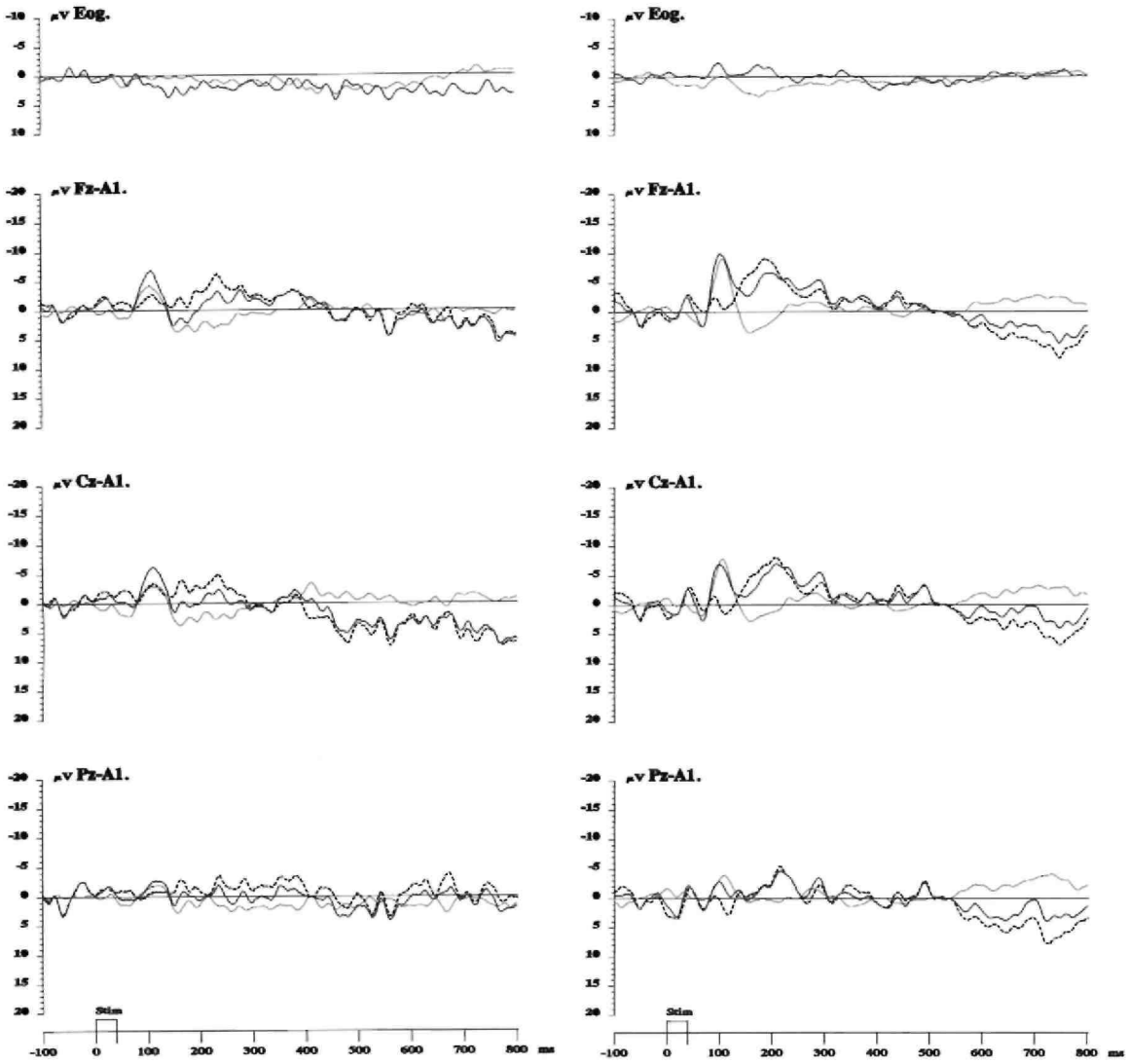
***Fig. 1**: Illustrative event-related potentials elicited by frequent (thin lines) and deviant (thick lines) tones, and the respective potential differences (i.e. the subtracted responses, dashed lines) in two subjects.*



3. Results

Fig. 1 presents two illustrative recordings obtained by two subjects. The mean MMN amplitude was -5.4 μV at Fz (SD = 3.0), -5.6 μV at Cz (SD = 3.2) and -4.4 μV at Pz (SD = 2.8). Mean MMN latency was 225 ms at Fz (SD = 20.7), 223 ms at Cz (SD=18.3), and 227 ms at Pz (SD=17.7). The mean temperament and character scores among the subjects were: NS=18.8 (SD = 6.0), HA=12.8 (SD = 5.2), RD=14.7 (SD = 3.1), P = 4.2 (SD=1.9), SD = 34.9 (SD = 7.8), CO = 33.0 (SD = 3.8), and ST = 9.7 (SD = 5.7).

The HA dimension was negatively correlated with the MMN amplitude recorded at Fz (r = -0.34, P = 0.005) and Pz (r = -0.25, P = 0.037) (Fig. 2). For the Cz electrode, the correlation did not reach the level of significance (r = -0.20, P = 0.10) (Fig. 2). No significant relationship existed between the other dimensions of personality and either the MMN amplitude or latency.

Fig. 2: *Relationship between mismatch negativity (MMN) amplitude and harm avoidance dimension from the TCI among 32 healthy subjects.*

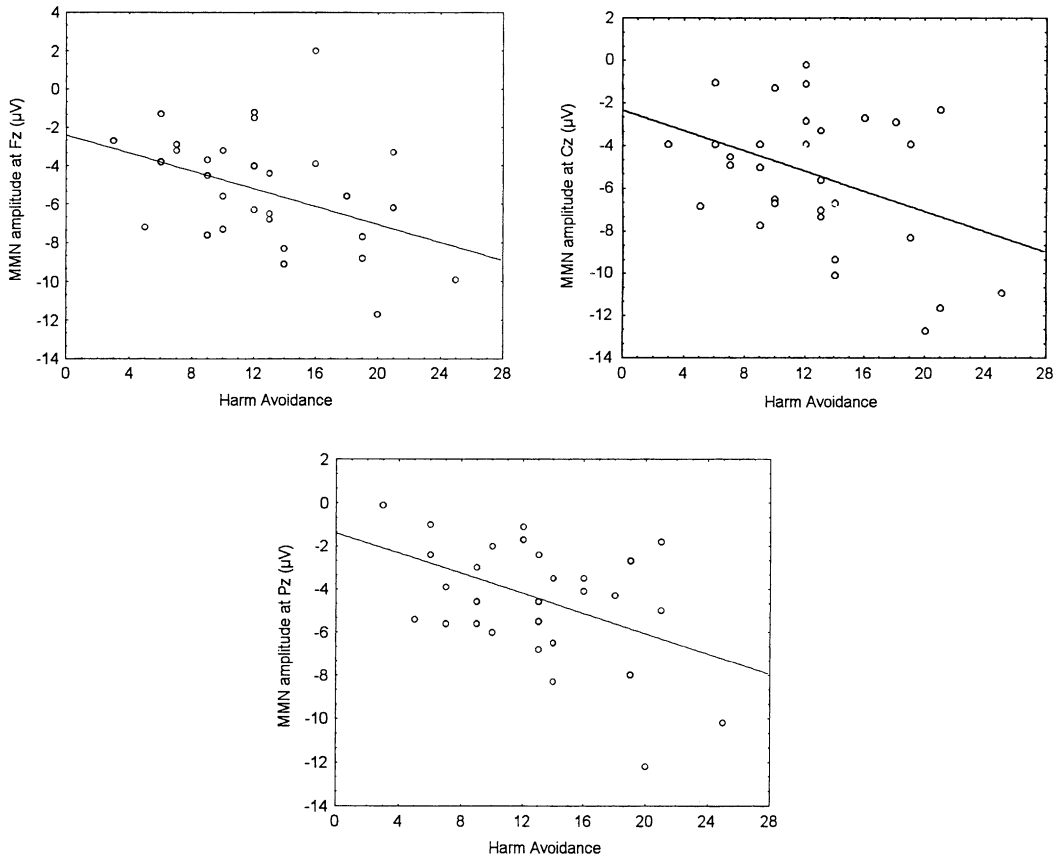


Table 1: *Comparison of personality dimensions and mismatch negativity (MMN) amplitude and latency between men (N= 18) and women (N= 14)*

	Women (*N* = 14)	**Men (*N* = 18)**	**Mann-Whitney *(z)***	***P* value**
MMN amplitude Fz	-5.2 μV±3.7	-5.5 μV±2.3	-0.20	0.83
MMN amplitude Cz	-5.7 μV±3.9	-5.1 μV±2.6	-0.45	0.64
MMN amplitude Pz	-4.8 μV±3.1	-3.9 μV±2.6	-0.89	0.37
MMN latency Fz	225.3 ms±18.5	224.7 ms ±22.7	-0.11	0.90
MMN latency Cz	222.8 ms±18.4	223.3 ms±18.8	-0.53	0.56
MMN latency Pz	227.7 ms±18.6	226.8 ms±17.6	-0.26	0.79
NS	21.0±7.8	17.0±3.5	-1.69	0.08
HA	13.6±4.7	12.1±5.6	-0.98	0.32
RD	16.3±3.1	13.4±2.6	-2.33	0.018
P	4.1 ±2.2	4.3±1.7	-0.53	0.58
SD	33.9±9.7	35.6±6.1	-0.60	0.54
CO	33.6±3.6	32.3±3.9	-0.56	0.56
ST	10.3±6.2	9.3±5.4	-0.09	0.92

Data are shown as mean±SD, with Mann-Whitney *U* test *(z)* and *P* values (NS: Novelty seeking, HA: Harm avoidance, RD: Reward dependence, P; Persistence, SD: Self-directedness, CO: Cooperativeness, ST: Self-transcendence).

3.1. Gender effect

No difference existed between men and women for either the MMN amplitude or latency (Table 1). Concerning TCI scores, women exhibited higher RD scores than men (Table 1).

The correlations between TCI and MMN were performed within both genders. Within the women's group, the HA dimension was negatively correlated with the MMN amplitude (Fz, r = -0.34, P = 0.08; Cz, r = -0.49, P =

0.014; Pz, r = -0.42, P = 0.03). The other dimensions were not related with either the MMN amplitude or latency. Within the men's group, the HA dimension was negatively correlated with the MMN amplitude at Fz (r = -0.35, P = 0.04), but this dimension was not correlated with the MMN amplitude recorded at Cz or Pz. The MMN amplitude recorded at Fz was correlated positively with the P dimension (r = 0.33, P = 0.05), whereas the MMN amplitude recorded at Cz was negatively correlated with the SD dimension (r = -0.34, P = 0.04). The other dimensions of personality were not related with the MMN amplitude or latency.

4. Discussion

The main result of this study is a negative correlation between the MMN amplitude and the HA dimension of the Cloninger's model. Since the MMN was measured with a real value (i.e. negative value) this indicates that higher MMN amplitude is associated with a higher score on HA, and inversely that lower MMN is associated with lower HA scores. It should be noted that this result is particularly true among women but less among men. The HA dimension corresponds to the tendency toward an inhibitory response (Cloninger & Svrakic, 1997; Cloninger et al., 1993). Individuals high in HA are pessimistic, fearful, shy, and fatigable. In contrast, individuals low in HA have little anticipatory anxiety or fear about danger, and consequently they are optimist risk takers. Interestingly, in the biosocial model of Cloninger, HA is linked with the behavioral inhibition system (BIS). More precisely, the BIS is activated in subjects characterized by higher scores on harm avoidance. This attitude is associated with higher MMN amplitude in the present study. This finding suggests that individuals who exhibit higher MMN amplitude are characterized by increased inhibitory processes.

Although the relationship between the MMN and the behavioral inhibitory system was not investigated in healthy subjects before, indirect findings from clinical studies may suggest some explanations. First, several studies have demonstrated that MMN is impaired in patients with schizophrenia (Alain et al., 1998; Catts et al., 1995; Javitt et al., 1995) due to a deficit in inhibitory functioning. Second, psychophysiological studies have demonstrated that some anxiety disorders are associated with increased signs of automatic processing caused by an increased behavioral inhibitory system. (Clark et al., 1996; Towey et al., 1993). Overall, these clinical studies suggest that automatic processing is altered in pathology characterized by an impaired inhibitory system (schizophrenia), and that automatic processing is increased in anxiety pathologies characterized by an enhanced inhibitory system. Therefore, the association between HA and an index of automatic processing (i.e. the MMN) found in the present study is in agreement with the clinical studies.

Interestingly, Hansenne (1999) reported a negative relationship between P300 amplitude and HA score in healthy subjects. Higher P300 amplitude was associated with lower HA scores. This indicated that P300 was negatively related with BIS. In the present study, the opposite results were obtained with the MMN. In fact, P300 reflects controlled processes, whereas the MMN index automatic ones. Taken together, these data suggest an opposite effect of the BIS on positive (P300) and negative (MMN) ERP components, and an opposite action of the BIS on controlled and automatic processes. Automatic processes are improved with the activation of the BIS although controlled processes are impaired with the activation of the BIS.

In the present study, the associations between personality and the MMN are particularly present for women and less among men. Since there are no differences between men and women for the MMN amplitude and not for the TCI (except for RD), this indicates that measures of automatic processing reflected by the MMN are associated with the BIS more particularly among women. Therefore, the HA dimension induces different automatic attitudes towards the processing of information mainly among women. Higher HA women exhibit higher MMN amplitude reflecting an increased BIS. It should be noted that gender differences have been reported concerning the relationships between P300 and extraversion. Polich and Martin (1992) reported that the negative correlation between P300 and extraversion was only found in men and not in women.

To our knowledge, there is only one other study in which the MMN was related with personality (Wang, Zhu, Pan, & Wang, 2001). In this study, personality was assessed according to the Zuckerman model of personality (Zuckerman, 1994). The results showed that MMN amplitude (absolute values) at Fz was positively correlated with Neuroticism-Anxiety, and negatively with experience seeking. Relationships exist between the dimensions proposed by Zuckerman and those proposed by Cloninger which permits comparisons between this study and the present one. More particularly NS is related with Impulsive Sensation Seeking, HA with Neuroticism-Anxiety, and C with Aggression-Hostility (Zuckerman & Cloninger, 1996). Therefore, the relationship between HA and the MMN amplitude in the present study is consistent with the correlation between Neuroticism-Anxiety and the MMN amplitude reported in the study of Wang et al. (2001). Unfortunately, the study of Wang et al. (2001) did not provide gender effects on the relationship between personality and MMN amplitude.

In conclusion, this study suggests that personality is related to MMN amplitude in healthy subjects. In the present study, MMN amplitude is linked to the harm avoidance dimension of the Cloninger model of personality. This finding is particularly true among women, but less among men, and indicates that personality dimensions induce different attitudes toward the processing of information. However, the preliminary nature of the presented results with respect to the statistical validity (type I error inflation with multiple significance tests) as well as to the highly selected sample (hospital staff) should be underlined. Then, further studies should be conducted to replicate these findings.

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