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P300 and personality: an investigation with the Cloninger's model

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Abstract

The relationships between P300 and personality have been explored mainly in reference to the model of personality described by Eysenck because of its biological bases. Recently, Cloninger and his colleagues have proposed a model of personality based on four temperaments and three characters. The Temperament and Character Inventory (TCI) is a 226-item self-questionnaire developed to assess these seven dimensions of personality. In the present study, the relationships between these dimensions of personality and P300 have been investigated in 43 normal subjects. The results show that P300 amplitude is positively correlated with the novelty seeking dimension and negatively correlated with the harm avoidance dimension. In contrast, the other dimensions of the TCI were not related to P300 amplitude. Moreover, P300 latency and reaction time were not associated with the TCI dimensions of personality. This study confirms that personality is related to P300. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

The P300 component of the Event-Related Potential (ERP) is a positive deflection which occurs when a subject detects an informative task-relevant stimulus. It has been used extensively for the study of cognitive processes in normal subjects and in psychopathology (Donchin and Coles, 1988; Picton, 1992). P300 reflects

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memory updating (Donchin and Coles, 1988), or context closure (Desmedt, 1981; Verleger, 1988). P300 is related to an external control which favors attentional mechanisms to the environment (Kok, 1990), and it perhaps represents the transfer of relevant information to consciousness (Picton, 1992). P300 amplitude is related to stimulus probability, stimulus significance, task difficulty, motivation, vigilance (Johnson, 1986; Sommer and Matt, 1990; Johnson, 1993), and also handedness (Alexander and Polich, 1995). P300 latency reflects the time of stimulus evaluation (Kutas et al., 1977). P300 latency is mainly influenced by the task complexity and it is only weakly influenced by response selection processes (McCarthy and Donchin, 1981; Smulders et al., 1995). Moreover, P300 latency could be heritable (Rogers and Deary, 1991).

Individual differences influence considerably both P300 amplitude and P300 latency in healthy subjects, for instance development (Courchesne, 1983), age (Polich, 1992; Iragui et al., 1993), gender (Polich, 1992, 1996), intelligence (Geisler and Polich, 1990; McGarry-Roberts et al., 1992) and personality (Simons et al., 1982; Daruna and Karrer, 1984; Pritchard, 1989 Orlebeke et al., 1989; DiTraglia and Polich, 1991; Cahill and Polich, 1992; Stelmack et al., 1993).

Concerning personality, most reports have explored the relationships between P300 and the introversion-extraversion dimension of Eysenck 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 (O'Connor 1983; Daruna et al., 1985; Polich and Martin, 1992). A somewhat similar effect was observed by DiTraglia and Polich (1991), who reported that extraverts displayed a greater decrease in P300 amplitude across trial blocks than introverts. However, opposite results were described by Cahill and Polich (1992). In general, these results are understood in terms of the greater amount of attentional resources that introverts invest in the processing of the target stimuli. However, level of attention was not directly manipulated in these studies so that differences in sensitivity to stimulation per se cannot be ruled out. Overall, these results are consistent with the biological bases of introversion (Eysenck, 1990). However, the relationships between the introverted and extraverted personality types and P300 are far from clear. Indeed, Pritchard (1989) has found no relationship between extraversion and P300 amplitude, but he has demonstrated a negative relation between neuroticism and P300 latency in male subjects. On the other hand, some studies have reported that P300 amplitude is related to different aspects of personality, for instance impulsivity (Daruna and Karrer, 1984), anxiety (Otten et al., 1995) and anhedonia (Simons et al., 1982; Miller et al., 1984).

Another interesting model of personality is the biosocial model of Cloninger. Over the past decade, Cloninger and his colleagues have developed a biosocial model of personality based on three fundamental dimensions: novelty seeking, harm avoidance and reward dependence (Cloninger, 1986, 1987). Some studies

suggest that personality traits defined by the Cloninger model are correlated with neurobiological features. Novelty seeking is defined as the tendency to respond actively to novel stimuli leading to pursuit of rewards and escape from punishment. Harm avoidance corresponds to the tendency toward an inhibitory response to signals of aversive stimuli that lead to avoidance of punishment and nonreward. Reward dependence is defined as the tendency for a positive response to signals of reward to maintain or resist behavioral extinction. According to this model, the three dimensions have been postulated to be inheritable and independent. Moreover, each dimension has been associated to a specific central neurotransmitter; novelty seeking to dopaminergic activity; harm avoidance to serotonergic activity; and reward dependence to noradrenergic activity. The Tridimensional Personality Questionnaire (TPQ) has been developed by Cloninger to assess these temperaments (Cloninger et al., 1991). Factorial analysis resulted in a good validation of novelty seeking and harm avoidance, but a poorer for reward dependence (Cloninger et al., 1991; Svrakic et al., 1991; Wetzel et al., 1992). Although this model has been criticized by several authors for its simplicity and its lack of theoretical bases (Gelder, 1987; Gray, 1987; Liebowitz, 1987; Zuckerman, 1988; Eysenck, 1990), many psychometric and neurobiological investigations have described results that contribute to the validation of this model (Cloninger et al., 1991; Svrakic et al., 1991; Mulder and Joyce, 1994; Wiesbeck et al., 1995; Hansenne et al., 1997, 1998a). Moreover, recent genetic studies have demonstrated that D4 dopamine receptor gene is associated with novelty seeking (Benjamin et al., 1996; Ebstein et al., 1996).

Recent work from Cloninger and his colleagues (Cloninger et al., 1991, 1993) has suggested that persistence must be separated from reward dependence. Moreover, the model has been extended with the addition of three measures of character: self-directedness, cooperativeness and self-transcendence (Cloninger et al., 1993; Svrakic et al., 1993). This extension is based on a synthesis of information about social and cognitive descriptions of personality development in humanist and transpersonal psychology. Self-directedness 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. The second character dimension of cooperativeness is formulated to account for individual differences in identification with and acceptance of other people. Cooperative individuals are described as socially tolerant, empathic, helpful and compassionate, whereas uncooperative individuals are described as socially intolerant, disinterested in other people, unhelpful and revengeful. Self-transcendence is a character associated with spirituality, and it 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 the seven dimensions of personality (Cloninger et al., 1994). Sample questions are listed in Table 1. The variances explained by the rotated factors after Promax rotation ranged from 4.4 to 2.0%, which is 17.7–8.0% of the total variance in the 25 factors (Cloninger et al., 1993).

In the model of Cloninger, the phenotypic structure of personality may differ from the underlying biogenetic structure because the observed behavioral variation is the result of the interaction of genetic and environmental influences. In contrast, the personality models of Eysenck and Gray assume that the observed phenotypic structure of personality corresponds with the underlying biogenetic variation. On the other hand, Zuckerman (1988) has asserted that Cloninger's description of novelty seeking is practically identical to the trait description of sensation seeking, but McCourt et al. (1993) have shown that the two dimensions are not identical.

In the biosocial model of Cloninger, novelty seeking is linked to the behavioral activation system and harm avoidance with the behavioral inhibition system. Conversely, the behavioral inhibition system is activated in subjects characterized by higher scores on harm avoidance. According with the energetical models of P300 proposed by Mulder (1986) and Kok (1990) P300 represents the cortical energy necessary to realize a cognitive operation in which an individual orients his attentionnal processes towards the novel stimulations of the environment. Then, amplitude variation of P300 component is usually considered as a sign of variation in intensity of activation/inhibition of neural structures in the brain by the task variables. Moreover, the theoretical constructs of 'surprise' and 'orientation' are associated both with TCI dimension (especially novelty seeking and harm avoidance) and P300 (Donchin, 1981). Therefore, the aim of this study is to investigate the relationship between P300 and the personality dimensions described by the TCI.

Table 1
Sample questions from the Temperament and Character Inventory (TCI).

TCI dimensions	Questions
Novelty seeking	I like to explore new ways to do things.
	When nothing new is happening, I usually start looking for something that is thrilling or exciting.
Harm avoidance	I often feel tense and worried in unfamiliar situations, even when others feel there is little to worry about.
	I have less energy and get tired more quickly than most people.
Reward dependence	I like to please other people as much as I can.
	I would like to have warm and close friends with me most of the time.
Persistence	I am usually so determined that I continued to work long after other people have given up.
	I am more a perfectionist than most people.
Self-directedness	I usually am free to chose what I will do.
	My behavior is strongly guided by certain goals that I have set for my life.
Cooperativeness	It is usually easy for me to like people who have different values from me.
	I like to be of service to others.
Self-transcendence	I believe that I have experienced extra-sensory perception myself.
	I often feel like I am a part of the spiritual force on which all life depends.

2. Method

2.1. Subjects

The study was conducted in 43 healthy subjects who were not familiar with psychophysiological methods. The sample comprised 18 men and 25 women with a mean age of 33.7 years (S.D. = 10.2). They were recruited among the staff of the University Hospital of Liège (Belgium). They all underwent a medical interview to exclude psychiatric or somatic disorders. This interview was based on clinical examination and past history. They completed a French version of the 226-item self questionnaire TCI within the day following the P300 recording. The translated version of the TCI used in the study has been recommended by Cloninger. It the translation was performed by Téhérani and Lépine and validated by Pélissolo and Lépine (1997). The protocol was approved by the Ethical Committee of the University of Liège Medical School and all subjects gave their informed consent.

2.2. Procedure

The P300 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% (target) were tones of 1000 Hz, 70 Db, 40 ms duration. The subjects were asked to press a button for the rare stimuli as quickly as possible.

2.3. Recording and data analysis

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 samples/s for 900 ms with a 200 ms prestimulus baseline. Trials on which the EEG or EOG exceeded 50 μV were rejected automatically.

P300 amplitude and latency were measured as the difference in voltage between baseline and the peak positive amplitude between 280 and 450 ms after the stimulus. Analysis of N100, P200 and N200 components will be reported elsewhere.

2.4. Statistical analysis

The statistical analyses were carried out using Statistica (4.5) for Windows (Statsoft, 1993). Rather than selecting groups of individuals that were high or low on dimensions and then analyzing group differences with analysis of variance, in the present study, a large sample of normal individuals was tested, and the

relationships between P300 and TCI data were assessed by Pearson product-moment correlation coefficients.

3. Results

Fig. 1 presents the grand average ERPs for the Fz, Cz, Pz electrodes, and the vertical EOG elicited by target tones. The mean P300 amplitude was 11.8 μV at Fz (S.D. = 7.7), 13.5 μV at Cz (S.D. = 7.1) and 14.6 μV at Pz (S.D. = 6.3). Mean P300 latency was 311 ms at Fz (S.D. = 23.2), 313 ms at Cz (S.D. = 26.1), and 309 ms at Pz (S.D. = 22.8). The reaction time (RT) ranged from 203 to 367 ms with a mean of 278 ms (S.D. = 57.4). Mean and standard deviations of the TCI dimensions are represented in Table 2. P300 amplitude and latency, reaction time and TCI scores did not differ between male and female subjects.

The relationships between P300 amplitude, latency and reaction time on the one hand and the TCI dimensions on the other hand are represented in Table 3. P300 amplitude was positively correlated with novelty seeking ($r = 0.50$, $P = 0.006$ at Pz) (Fig. 2), and negatively correlated with harm avoidance ($r = -0.36$, $P = 0.03$ at Pz) (Fig. 3). In contrast, the other dimensions of the TCI were not related to P300 amplitude. Moreover, P300 latency and reaction time were not associated with the TCI dimensions of personality.

The correlations among the four dimensions of temperament and the three dimensions of character are summarized in Table 4. The significant correlations relate harm avoidance with novelty seeking, and cooperativeness with novelty seeking on one hand and harm avoidance on the other hand.

4. Discussion

The main findings of the present study are that P300 amplitude is positively related to the novelty seeking dimension of the TCI and negatively associated with the harm avoidance dimension. The other personality dimensions are not related to P300 amplitude. Finally, P300 latency and reaction time are not associated with personality dimensions described by the TCI.

In the biosocial model of Cloninger, novelty seeking is linked to the behavioral activation system and harm avoidance with the behavioral inhibition system. More precisely, the behavioral activation system is mainly activated in subjects characterized by higher scores on novelty seeking. This tendency is associated with a higher P300 amplitude in the present study. Conversely, the behavioral inhibition system is activated in subjects characterized by higher scores on harm avoidance. This attitude is associated by a lower P300 amplitude in the present study. However, since novelty seeking and harm avoidance are correlated, their relationships with P300 amplitude are not independent. Taken together, these results are consistent with the energetical models of P300 proposed by Mulder (1986) and Kok (1990). These models suggest that P300 represents the cortical energy necessary to realize a

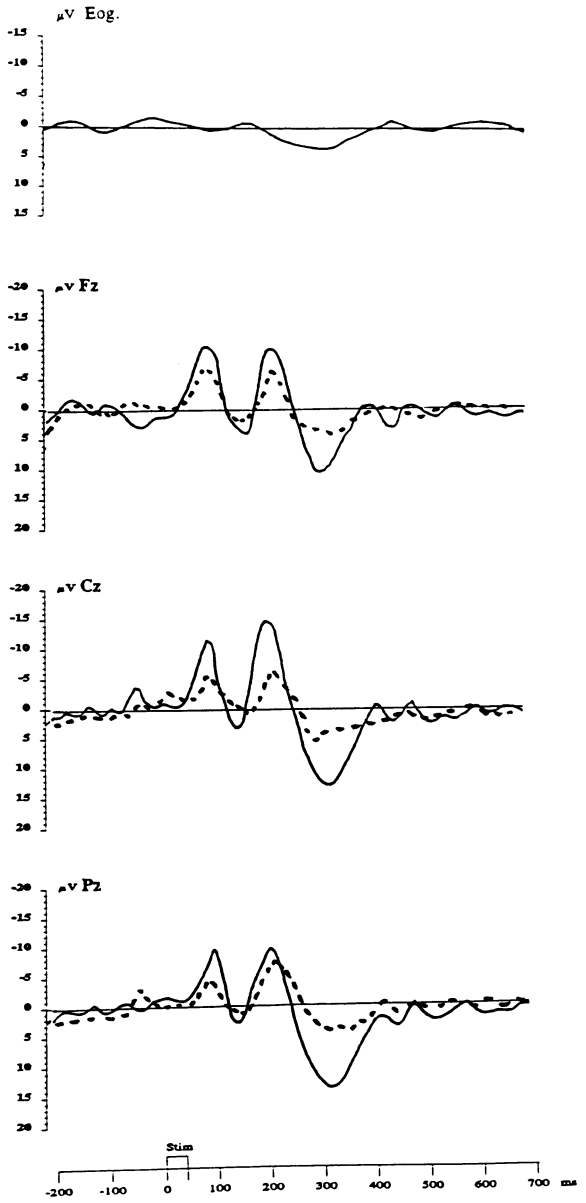

Fig. 1. Grand average ERPs of the Fz, Cz, Pz electrodes and vertical EOG eliciting by target tones. Solid line indicates the response to rare tones; dashed line, the response to frequent tones.

cognitive operation in which an individual orients his attentionnal processes towards the novel stimulations of the environment. Then, amplitude variation of P300 component is usually considered as a sign of variation in intensity of activation of neural structures in the brain by the task variables.

Table 2
Mean and S.D. of TCI dimension scores ($N = 43$).

TCI dimensions	Mean	S.D.
Novelty seeking	20.3	6.8
Harm avoidance	13.4	5.9
Reward dependence	16.8	4.1
Persistence	3.9	2.5
Self-directedness	33.3	5.4
Cooperativeness	31.9	4.3
Self-transcendence	10.2	5.0

The relationships between novelty seeking and harm avoidance dimensions of the TCI on the one hand and P300 amplitude on the other hand could be also explained by their underlying neurobiological bases. Indeed, novelty seeking is mediated by the mesocortical dopaminergic system, and harm avoidance is related to serotonergic activity. Several studies have confirmed these associations (Wiesbeck et al., 1995; Hansenne et al., 1997), although others studies have not (Limson et al., 1991; Hansenne and Ansseau 1998). On the other hand, many studies have demonstrated that P300 amplitude is modulated by dopaminergic activity (Klorman et al., 1979; Hansenne et al., 1995; Jonkman et al., 1997). Moreover, the group have recently demonstrated that 5-HT1A activity is related to P300 amplitude in healthy subjects (Hansenne et al., 1998b). However, in addition to these neurobiological influences, P300 is also sensitive to many psychological factors, for instance

Table 3
Pearson correlation coefficients between P300 amplitude, latency and reaction time (RT) and the personality dimensions of the TCI among 43 healthy subjects[a]

	TCI dimensions						
	Temperaments				Characters		
	NS	HA	RD	P	SD	CO	ST
P300 Amplitude							
Fz	0.11	−0.15	−0.03	−0.22	−0.01	0.06	0.05
Cz	0.41**	−0.29*	0.04	0.06	−0.18	−0.17	−0.02
Pz	0.50**	−0.36*	0.12	0.22	−0.20	−0.14	−0.08
P300 latency							
Fz	0.12	−0.02	−0.17	0.07	−0.02	−0.16	0.03
Cz	0.18	0.01	−0.04	0.11	−0.09	−0.21	0.16
Pz	0.17	−0.20	−0.07	0.23	−0.05	−0.03	0.25
P300 RT	0.15	−0.20	−0.10	0.08	−0.16	0.20	0.25

[a] NS: novelty seeking; HA: harm avoidance; RD: reward dependence; P: persistence; SD: self-directedness; CO: cooperativeness; ST: self-transcendence; RT: reaction time.

* $P < 0.05$.

** $P < 0.01$.

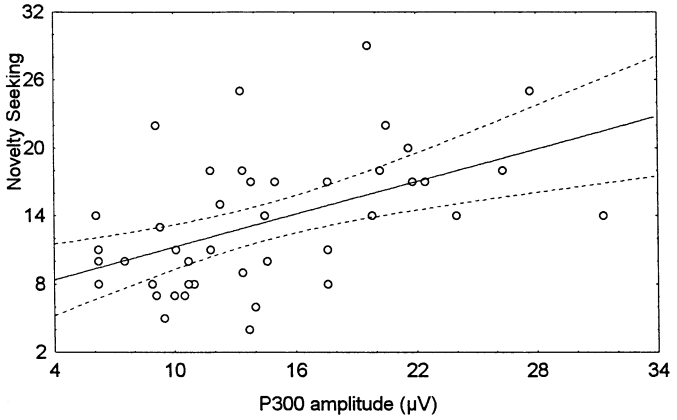

Fig. 2. Relationship between P300 amplitude recorded at Pz and novelty seeking dimension of the TCI among 43 healthy subjects ($r = 0.50$, $P = 0.006$).

motivation and vigilance (Sommer and Matt 1990; Johnson, 1993). Then, it is possible that high as compared to low novelty seeking is associated with differences in their attitudes during the P300 discrimination task which influence motivation and vigilance and, as a consequence, the P300 amplitude.

In the present study, both P300 latency and reaction time are not associated with any particular personality dimensions of the TCI. These results differ significantly from studies which have demonstrated that some aspects of personality assessed by different instruments were associated with P300 latency and reaction time. For instance, Pritchard (1989) has reported an inverse relation between neuroticism dimension and P300 latency in male healthy subjects. Moreover, Stelmack et al. (1993) have found that individuals with higher neuroticism scores exhibited faster P300 latency and slower reaction time.

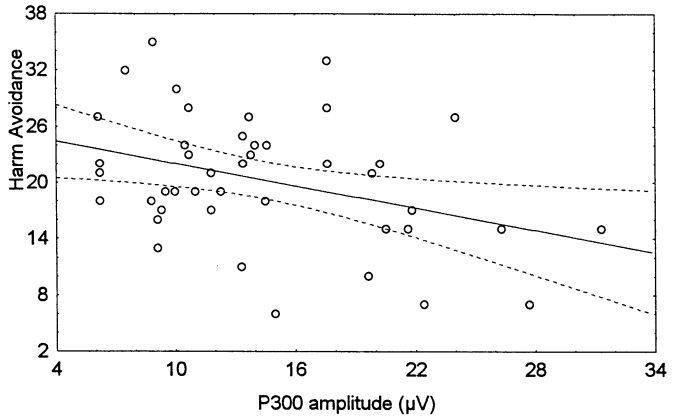

Fig. 3. Relationship between P300 amplitude recorded at Pz and harm avoidance dimension of the TCI among 43 healthy subjects ($r = -0.36$, $P = 0.03$).

Table 4
Correlations among temperament and character scales within the control group[a]

	NS	HA	RD	P	SD	CO
NS	…	…	…	…	…	…
HA	**−0.58**	…	…	…	…	…
RD	0.03	0.23	…	…	…	…
P	−0.41	0.21	0.27	…	…	…
SD	−.001	−0.36	−0.14	0.04	…	…
CO	**0.46**	**−0.51**	0.23	0.14	0.33	…
ST	0.07	−0.09	0.07	0.28	−0.17	0.21

[a] Bold coefficients are significant at $P<0.01$. NS indicates novelty seeking; HA, harm avoidance; RD, reward dependence; P, persistence; SD, self-directedness; CO, cooperativeness; ST, self-transcendence.

Most reports of the influence of personality on P300 have been carried out with the Eysenck Personality Inventory (EPI) (Pritchard, 1989; DiTraglia and Polich 1991; Stelmack et al., 1993). A consistent result of the studies which relate P300 to this personality dimension is that introverts exhibit higher P300 amplitude than extraverts. Since the relationships between the biosocial model of Cloninger and the model proposed by Eysenck (1991) are far from clear, it is difficult to compare the present results with those from studies using Eysencks model. In fact, to the author's knowledge, two studies have examined the relationships between these two personality model. First, Cloninger (1988) has reported that novelty seeking is correlated with extraversion and neuroticism, and that harm avoidance is correlated with neuroticism and negatively with extraversion. Mulder and Joyce (1994) have reported that harm avoidance scores were positively correlated with neuroticism scores and negatively correlated with extraversion scores, and that novelty seeking scores correlated with psychoticism scores and extraversion scores. Based on these relationships, the present findings are opposite to those typically reported. One possible explanation is that, as suggested by a recent study (Heath et al., 1994), the personality systems of Cloninger and Eysenck are not simply alternative descriptions of the same dimensions of personality, but rather each provide incomplete descriptions of the structure of the heritable personality differences. Moreover, Cloninger and Eysenck associated opposite psychological explanations of related dimensions: in the Cloninger model, novelty seeking is associated with behavioral activation and enhanced attentionnal resources, although the model of Eysenck associated extraversion (positively correlated with novelty seeking) with cortical inhibition and weak attentionnal resources'. Again, harm avoidance is related to behavioral inhibition and introversion is related to cortical arousal.

In conclusion, this study confirms that personality is related to P300 amplitude in healthy subjects. In the present study, P300 amplitude is linked to the behavioral activation and behavioral inhibition systems implicated in personality. 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. Moreover, a complex task in which novelty and avoidance could be manipulated should be more adequate than the simple P300 oddball task used in the present study.

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