

P300 wave: A comparative study of impulsive aggressive criminals

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Abstract

Event-Related potentials are a simple non-invasive neurophysiological method enabling to comprehend certain aspects of the cognitive processing of information in humans. The best-known component of Event-Related Potentials is the so-called P3 wave. Alterations in the parameters of P300 wave have been discovered in certain personality disorders and in persons with impulsively aggressive behaviour. The purpose of this study is to investigate the changes of these parameters, especially an amplitude and latency in the place of Pz electrode. We examined 15 persons with the impulsive aggressive behaviour and compared them to a population comparable of normal age, gender and approximate degree of education. We used P300 auditory and a neuropsychological Eysenck IVE battery. The results showed that significantly lower amplitudes had been found in the aggressive impulsive subjects as compared to the control group. No statistically significant differences have been discovered in the latency. These results seem to confirm previous studies.

1. INTRODUCTION

The neurophysiological research of aggressive behavior, in particular of its impulsive form, dates back to 1943 when an EEG investigation in this field was applied for the first time (Hill and Sargant, 1943). According to contemporary theories, the aggressive behavior can be divided into three basic types. First, it is aggression caused by disease, particularly the influence of psychotic symptoms, delusions and hallucinations (Vevera et. al, 2005); second, it is planned, non-impulsive aggression, without any concomitant affect; and last, impulsive aggression with no premeditation (Barrat et al., 1997). An intermittent explosive disorder classified under DSM IV can also be included in the latter.

Event-Related potentials are a simple non-invasive neurophysiological method that can grasp certain aspects of the cognitive processing of information in a human. The best-known and most important component of cognitive evoked potentials is the so-called P300 wave, which is not only of experimental but also of increasing clinical significance. Changes in its latency, amplitude and topography have been described in a wide range of diseases (Hruby and Marsalek, 2003). Apart from other cases, alterations in the parameters of P300 wave had been discovered in some personality disorders and in individuals with impulsive aggressive behavior (Kiehl et al. 1999; Houston and Stanford, 2001). The majority of authors agree that a lesser amplitude of the P300 wave is typical of the impulsive violent aggressors, while prolonged latency

has been more frequently described in the individuals with planned or other type of aggressiveness (Bond and Surguy, 2000). A correlation of the degree of violent behavior and the latency of P300 has also been discovered, which is the presumed indicator of the speed of cognitive processing or its disturbance, particularly in such persons. Thus, a specific deficit probably exists in the cognitive process in such persons.

In this study the same author also demonstrated prolonged latency and lateralization of the P300 wave caused by the auditory paradigm in aggressive, prosecuted individuals as compared to the normal population. On that basis the author stated that the latency of P300 wave correlated with the degree of violence and the violent behavior is thus in correlation with certain cognitive functions. Those findings are to a certain degree in contradiction with other findings that, in part, were possibly explained by the fact that the given series included rather the individuals with the non-impulsive form (Drake *et al.*, 1988). It was further demonstrated that in individuals who had an impulsive violent behavior pattern, the frontal lobe region was apparently disturbed, and that points to a possible disturbance of executive functions and a cognitive deficiency altering the processing of unexpected information (Kiehl *et al.*, 1999; Mathias and Stanford, 1999). The study of Branchey summarized hitherto published papers on the subject and showed that aggressive alcohol addicts had a lesser amplitude than the non-aggressive ones (Branchey *et al.*, 1988). Furthermore, a negative correlation between the Buss-Durkee Hostility Inventory and the size of P300 amplitude has been found. In that study the alcohol addicts had fathers who had similar problems - the combination of alcoholism and aggressiveness can thus determine two types of alcoholism. Aggressiveness in one of the types can be correlated with a diminished amplitude rather than with alcohol addiction as such, that being in agreement with other certain researches (Cloninger *et al.*, 1981).

The study of Raine and Venables (1988) to the contrary demonstrated higher amplitude in the individuals with impulsive aggressive behavior, that being in sharp contradiction to other results; that was explained as a possibly increased attention towards irritating stimuli in the impulsively aggressive persons. This author in his prospective study described shorter latency in P300 wave and a greater amplitude in N1 wave in children. That finding, according to the author, was predictive of future violent and criminal behavior of such individuals on a 74% confidence level (Raine *et al.*, 1990). The research of Barrat *et al.* (1999) and the study of Gerstle *et al.* (1999) pointed to the differences between the so-called impulsive and non-impulsive aggressiveness, wherein the individuals with the impulsive type of aggressiveness had significantly decreased amplitude of the P300 wave.

Through a modification of the basic paradigm, other authors demonstrated in their studies a greater alteration of the amplitude in the impulsively behaving in-

dividuals when applying third unexpected stimulus in a row (Mathias and Stanford, 1999). Bond and Surguy studied the individuals with the non-impulsive type of aggressive behavior (Bond and Surguy, 2000). The results showed a prolongation of latency in the P300 wave while preserving unaltered amplitudes as compared to the control population. It follows from the above-mentioned studies that the overwhelming majority of authors currently agree that non-impulsively motivated aggressiveness is mostly connected to the prolonged latency, while impulsively emotional aggressiveness is usually associated with the decreased amplitude.

Four basic hypotheses have been set at the beginning of the present study. In the first one it is stated that the group of impulsive aggressive delinquents (IA group) had a lesser P300 amplitude than the control group of non-delinquents (n=15). In the second, it is postulated that the group of impulsive aggressive delinquents (IA group) had a prolonged latency of P300 than the control group of non-delinquents (n=15). In the third, it is said that the individuals from the group of impulsive-aggressive delinquents differ from the control group with the impulsivity score (I) in the Eysenck IVE questionnaire. In the fourth hypothesis it is stated that the impulsiveness in the Eysenck IVE questionnaire correlates negatively with the P300 amplitude.

The presented study had several objectives. Firstly, to determine whether the persons committing impulsive, violent criminal acts (affectively motivated and affectively aggressive) and the non-delinquent population differ in the following parameters: P300 amplitude and P300 latency. Secondly, to establish how the impulsive violent behavior is associated with the scores in the Eysenck IVE questionnaire, especially with the Impulsivity subscale (I). Thirdly, to find how the Impulsivity (I) in the Eysenck questionnaire is associated with the P300 amplitude. Fourthly, to ascertain how the occurrence of abnormalities in alpha and heart frequency is associated with the impulsive violent behavior. Psychophysiological under-arousal in the criminal behavior is defined, among other things, by a decreased heart frequency, decreased skin conductivity, and the occurrence of low-frequency alpha waves in the EEG (Raine, 1988).

2. METHODS

Two groups of persons are compared in the study. In the first group (n=15) the perpetrators of criminal actions that have been assessed to be impulsive, not planned, affectively motivated and affectively aggressive (AI group) were included. The second group, the control one (n=15), included individuals who had not committed any criminal offence (NI). The first group, the group of impulsive aggressive delinquents, included the delinquents behaving violently, impulsively and aggressively, whose behavior was assessed by the Police of the Czech Republic as being a criminal offence, e.g. murder, bodily injury, fight or attack on a public official.

The perpetrators of violent criminal actions that were evaluated as being impulsive, unplanned, affectively motivated and affectively aggressive were included. Their criminal actions were not influenced by any psychotropic substance, these subjects had not consumed any alcohol prior to the criminal offence, and had not been judicially punished. A character – the manner of performing a criminal offence was, as mentioned above, stated by at least two independently investigating psychiatrist-experts in the area of healthcare – psychiatry. This means that they conducted a structured interview required for the preparation of expert valuation for which the opinion of the expert – experts on the character of performance of the criminal offence itself, i.e., on the presence or absence of the impulsive component, is necessary.

It further applied for the A1 group that they scored 8 and more on BDHI "irritability subscale" (Buss Durkee, 1957) which did not apply for anybody from the control NI-group. That means that the group of the "impulsively aggressive" was defined by means of the criminal offence itself, by the manner of its performance (considered by the police and experts in the area of health service - psychiatry) and scoring on BDHI subscale. In addition, everybody from the A1 group stated another impulsively aggressive activity in a self-report test than the one for which they were prosecuted within the last 3 months. This means they confessed they had been aggressive towards the people or things in the form which can be considered unplanned and thus impulsive. For example, breaking the furniture in a quarrel with a partner in the time they were prosecuted for a serious violent criminal offence with the perspective of being sentenced for another, prior violent criminal offence!

All of those included in the first group were investigated by one of the authors, an expert witness, in 2002 - 2005. The subjects in the first group were investigated and examined maximally within one year after committing the criminal offence. The first group subjects had to have, in addition, at least one episode of behavior that can be described as impulsively violent against their surroundings and was the object of prosecution towards objects or persons, within a period of two months prior to the measuring itself. None of the subjects suffered any serious internal, neurological or psychiatric disease except for personality disorders that were admitted. In the IA group F60.2 dissocial personality disorder was present, according to DSM IV, six times. The first group, the impulsive aggressive delinquents, comprised of men prosecuted for a violent offence that has been assessed by a healthcare expert in psychiatry, who is one of the authors, as being unplanned and with affectively conditioned motivation. The control group comes from among the friends of the authors [nobody from the control group (N1) was prosecuted, was a perpetrator of a violent criminal offence or scored more than 8 on the BDHI subscale]. In the study, the persons from the two groups were paired

by age (+/- 1year), gender - both groups were of males only, and education status. The mean age of the subjects of the study was 38; the oldest was 53 and the youngest 24. Decisive in the comparative studies of delinquents and the formation of series is the exact delimitation of the way the offence had been carried out, accordingly in our case it has to be stressed that the group of "impulsively aggressive delinquents", behaving violently, and prosecuted, is a group having an affectively conditioned motivation. The offence had not been planned. Excluded were also the violent individuals in whom the so-called deviant motivations were diagnosed which are characterized by the fact that the individual has a mental abnormality or defect, which fundamentally influences his motivation.

The condition for inclusion in the study was signing of informed consent. Subjects entering the study underwent the following testing: a clinical history, the Event-Related Potentials, the P300 wave with inter stimulus interval (ISI) 2s and inter stimulus interval (ISI) 3s - only the Py electrode was evaluated; it was monitored in 10-20 system with an apparatus from Alien Technik. The subjects were investigated in auditory modality with target stimulus of 2000Hz parameters, and indifferent stimulus of 1000Hz frequency. The investigation was conducted in a sound proofed chamber equipped with a Faraday cage. The stimuli were sent at the ratio of 20% target stimuli and 80% of the indifferent ones. The examined subject sat in a chair with closed eyes and his task was to listen to each stimulus and count those that had been marked beforehand and described as target stimuli. There were 20 target stimuli in one series.

Further, an investigation through the Eysenck IVE questionnaire was carried out, translated and validated for its use in the Czech Republic and focused on the (I) impulsivity subscale. There are valid common rules on the implementation of psychological questionnaire methodologies for administering the questionnaires. The questionnaires are applicable individually or in collective surveys. How the interrogated person should proceed is always presented on page one of each questionnaire. The questionnaire was implemented on an individual basis. Evaluation and scoring was performed directly on the test sheet with the aid of stencil patterns with printed rectangles covering the symptomatic answers in the corresponding scales. The sum of circled rectangles gives the score in each of the scales.

Designation of each of the scales: I, V, E; I = Impulsiveness, V = Venturesomeness, E = Empathy. ECG - applies as a component for the calculation of heart frequency. EEG, examination in the 10 - 20 system in which the following parameters were assessed: abnormalities of basic activity, e.g., the abnormalities of alpha activity (only 7.5-8 Hz PO frequency was evaluated), the abnormalities of beta activity, the abnormal slow activities of theta and delta, epileptiform graphic elements and the patterns of uncertain significance. In each EEG investigation the following activation methods were ap-

Table 1. Descriptive characteristics of variables in the main group.

	Mean	Median	Mode	Frequency of Mode	Minimum	Maximum	Variance	Std.Dev.
Age	38.40	37.00	Multiple		24.00	53.00	105.26	10.26
Amplitude 2s	4.31	4.00	3.6	3.00	3.00	6.10	0.90	0.95
Latency 2s	337.80	341.00	345	2.00	320.00	360.00	160.31	12.66
Amplitude 3s	4.17	3.80	3.8	4.00	2.70	5.80	0.94	0.97
Latency 3s	330.53	332.00	345	3.00	246.00	356.00	670.98	25.90
I	12.13	12.00	12	5.00	9.00	14.00	2.12	1.46
V	7.20	7.00	9	4.00	4.00	10.00	3.60	1.90
E	10.67	10.00	10	8.00	9.00	13.00	1.24	1.11
Puls	70.47	70.00	62	2.00	61.00	82.00	47.98	6.93

Table 2. ANOVA for differences between impulsive a non-impulsive group.

	MS Model	SS Residual	df Residual	MS Residual	F	p
Amplitude 2s	726.19	80.87	28.00	2.88	251.42	0.00
Latency 2s	22.53	4840.13	28.00	172.86	0.13	0.72
Amplitude 3s	764.07	81.68	28.00	2.91	261.91	0.00
Latency 3s	616.53	11675.33	28.00	416.97	1.48	0.23
I	80.03	41.47	28.00	1.48	54.04	0.00
V	76.80	74.00	28.00	2.64	29.06	0.00
E	0.03	26.27	28.00	0.93	0.04	0.85
Puls	58.80	1000.67	28.00	35.73	1.65	0.21

Table 3. Correlations of variables in aggressive-impulsive group the AI group.

	Age	Amplitude 2s	Latency 2s	Amplitude 3s	Latency 3s	I	V	E	Puls
Age	1.00	0.20	0.71	0.36	-0.06	-0.03	-0.04	0.11	-0.10
Amplitude 2s	0.20	1.00	0.24	0.91	-0.14	-0.02	-0.08	0.21	0.35
Latency 2s	0.71	0.24	1.00	0.477	0.12	-0.21	0.07	0.06	0.19
Amplitude 3s	0.36	0.91	0.47	1	-0.15	-0.13	-0.00	0.26	0.27
Latency 3s	-0.06	-0.14	0.12	-0.15	1.00	0.33	-0.23	-0.07	-0.42
I	-0.03	-0.02	-0.21	-0.13	0.33	1.00	-0.78	0.07	-0.43
V	-0.05	-0.08	0.07	0.00	-0.24	-0.79	1	-0.64	0.54
E	0.11	0.21	0.06	0.25	-0.07	0.07	-0.64	1.00	-0.40
Puls	-0,09	0,34	0,19	0,27	-0,41908	-0,43116	0,53	-0,39	1

Significant correlations are highlighted ($p < 0.001$)

plied: hyperventilation – took 4 minutes (2 minutes - oral and 2 minutes - nasal). Upon the termination of hyperventilation, taking of EEG continued for other 2 minutes, the dynamics of pathological changes were assessed, how rapidly they recede after the hyperventilation. Normally, there should be no changes during the hyperventilation, the temporarily lowered frequency is yet considered to be normal. In photo-stimulation the subject was stimulated with the flashes of 1–35 Hz light. Upon stimulation the alpha frequency changes in coincidence with the blinking; in harmonic variations the case is with the multiples, in sub-harmonic variations with the proportions of alpha. Nothing should be altered except for those changes. Epileptic manifesta-

tions may occur in photogenic epilepsy. Apnea: the investigated person inhaled and held his breath. He held his breath as long as he could (acidosis and vasodilatation appears during the apnea). The information on the reserves in the brain is obtained; specific graphic elements are activated with the epileptics. The measuring of the heart frequency had been executed an hour before the taking of EEG and measuring of cognitive evoked potentials and then again, after five minutes; the mean heart frequency was calculated from these values and the values readable from the ECG (a twelve-by-pass EKG of SEIVA branch) taken after measuring the heart rate. It was measured after five minutes of sitting at ease in a room with 20 °C temperature. The heart rate was

determined by the measuring - counting of R-waves in a minute).

All the investigations were performed at the Department of Psychiatry, First Faculty of Medicine, Charles University, and were evaluated by the authors.

3. RESULTS

We used ANOVA distribution analysis and Pearson's product moment correlation coefficient in the statistical analysis of the sample. Table 1 shows basic statistical characteristics of both the AI and NI groups. A statistically significant difference between the amplitudes in the impulsive individuals and in the control group ($F = 251,418$; $p < 0.001$), as well as in the values on the (I) subscale of Eysenck IVE ($F = 54,041$; $p < 0.001$) (Fig. 1) is apparent from the results. These findings were confirmed by ANOVA distribution analysis as shown in Table 2. No statistically significant differences in the P300 latency have been found. No statistically significant correlation (Table 3) has been found among the variables under the follow-up in the studied group. The findings confirm those of other authors (Barrat *et al.*, 1997) on the relation of impulsiveness and P300 wave parameters. The supposition of a statistically significant correlation between the (I) subscale and the amplitude of wave P300 has not been confirmed, however, that may be due to the insufficient size of the studied group (Table 3). As far as the abnormalities of heart frequency and the so-called "sub-alpha" probably associated with the under-arousal is concerned, it has not been confirmed in our group to a statistically significant degree. That result can also be ascribed to the insufficient size of the group.

4. DISCUSSION

Our results confirm previous findings of which almost all show that the patients with the impulsive aggressiveness, in contrast to the norm, have to a significant degree, decreased the amplitude of the P300 wave. In the group studied by us we demonstrated no differences in P300 latency between the aggressive and non-aggressive behavior. On the other hand, some studies of the individuals with the predatory form of aggressive behavior reveal prolongation in latency that could point to a certain cognitive deficit in such persons (Bond and Surguy, 2000). However, no predatory aggressors were included in our series, in each case only affectively aggressive individuals were in question. The results of neuropsychological testing unequivocally point to an increased sub-score of impulsiveness in the Eysenck IVE questionnaire in the individuals with impulsive aggressivity as compared to normal persons. Our series of delinquents with impulsive-aggressive behavior were foremost formed on the basis of the existence of a criminal offence that had been classified by an expert witness as being affectively conditioned, impulsive

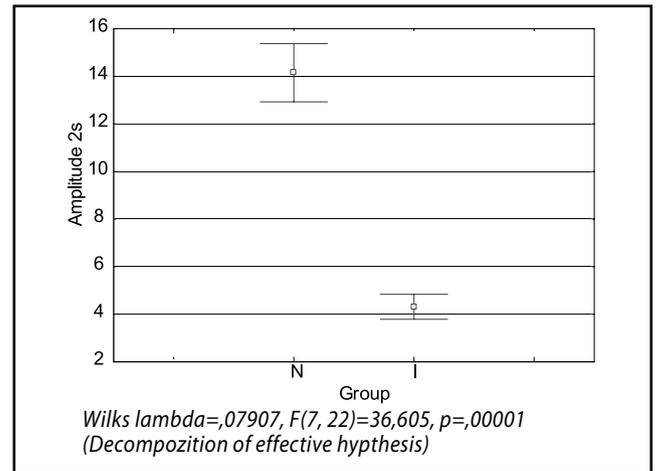


Figure 1. Difference between the amplitudes 2s in the impulsive individuals and the control group.

and violent. Motivation for the criminal offence was affectively conditioned. There was always a strong emotion in play, usually fear, despair, long-standing hatred that did not correlate with any offence according to the plan. The violence applied does not lead any further. It is bound to emotion and determined against the victim. The perpetrator has usually no program for the following period. Another variant was a situational, provoked violence under which the perpetrator and the victim get into a critical conflict situation. Strong emotions were usually projected in the mode of committing the offence. In most cases the place of the offence carried the signs of the perpetrator's intense excitement (Cirtkova, 2000).

Those individuals confirmed their permanent pattern of impulsive violent behavior in the self-report test (tendency towards the violently impulsive behavior even out of bonds of the respective criminal offence investigated by the police). The Eysenck (I) sub-scale has proven to be a very simple, applicable scale method capable of discerning the impulsively and non-impulsively behaving individuals. The results of the present study are thus in agreement with all preceding papers, except of the Raine's one that shows exactly the opposite, this being explained by the methodology of that study (Raine and Venables, 1988). With respect to the alteration of P300 wave parameters, such as the amplitude and latency, which is most probably generated in cortex regions according to recent studies - subcortical regions contribute to the generation of the p300 wave only indirectly (Hruby and Marsalek, 2003; Knight, 1998) - it is probable that the cognitive deficit, which is one of the possible causes of the impulsive form of aggressive behavior, is located particularly in the cortical region. It seems that this hypothesis is being confirmed by the neuropsychological tests demonstrating cognitive deficits in such individuals, e.g. the deficit in the area of speech or in the area serving for the dis-

cernment of emotional states; or the inability to learn from prior mistakes (Best *et al.*, 2002).

Further evidence of the existence of a specific cognitive deficit in the patients with the impulsively aggressive form of behavior are the results of studies with the application of phenytoin in the patients with this disorder, pointing to the decrease of amplitude and, simultaneously, to the diminishing of the readiness for the impulsive actions, especially upon administration of that drug (Chung *et al.*, 2002). Similarly, the administration of cocaine and other amphetamines leads to a decrease of amplitude and increase in readiness for impulsive actions (Moeller *et al.*, 2002). Another confirmation are the results of the research study of the parameters of wave P300 in the individuals suffering with the alcohol addiction syndrome, disinhibited and behaving impulsively-aggressively (Volavka, 1990).

Differences between impulsive and predatory aggressivity may thus be based in neurobiology, in the cognitive and attentive system of the neocortex, when the individuals with impulsive aggressivity apparently have a disorder in the frontal automatic sensory system and a disorder in the system of learning from past mistakes, and a deficit in the cognitive system of speech. The frontal serotonergic deficit may lead to the impulsive aggressive behavior, a disorder in automatic sensory response functions that are disrupted in the impulsively aggressive individuals (Best *et al.*, 2002). Cloninger described the correlation of increased impulsiveness and hypofrontality in the individuals by means of the second type of alcohol addiction in which a significant hereditary component has been described (Cloninger *et al.*, 1981). The possibility of a connection between the existence of sub-alpha which can be one of the causes of the decreased amplitude of wave P300 and which is associated with the under-arousal of the brain (the considered reason for the aggressive behavior) and the base for the worsened sensory filtering and processing of the entering information has not been statistically demonstrated in our series. Likewise, the connection between the heart frequency, as another possible manifestation of the under-arousal, and the P300 wave has not been demonstrated.

The results of our study seem to confirm the previous researches and point to a significant decrease of the amplitude of P300 wave in the IA individuals included in the study on the basis of committed offences. These results also correlate with the (I) subscale of the Eysenck IVE questionnaire, while hypothetical correlations have not been proven in our study to a statistically significant degree. It follows from what has been presented that the parameters of P300 wave are a sensitive but not very specific marker of the impulsiveness, just as the Eysenck IVE questionnaire. The results further suggest that a cognitive deficit and/or a deficit in the attentive system and the system of the discrimination of sensory information in the impulsively aggressive individuals exist. For further research and practice one of

the ways of influencing one of the forms of aggressive behavior is thus confirmed and suggested.

In the group investigated by us we demonstrated statistically significant differences in the P 300 values and impulsively aggressive delinquents and control subjects, which can in the future be important, e.g., for the investigation of aggressive behaviour within unmanaged affection. In our opinion it is necessary further to investigate the differences in the P 300 values, especially among the individual types of criminal offences and mainly the differences among the various forms of the demonstration of violence of a criminal nature.

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