

PRACE POGLĄDOWE

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Neurobiological factors in the development of psychopathic traits in children and adolescents – research review

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ABSTRACT

In this paper we provide an overview of the recently performed research on neurobiological foundations of psychopathy in children and adolescents. Cognitive and affective-emotional processing deficits typical for psychopathic individuals are often associated with abnormal brain structure and function, particularly the amygdala and orbito-frontal cortex. For example, there is some evidence, although limited, that lower cortisol levels is being associated with psychopathic-like traits in children and adolescents. Integrated perspective on role of some hormones (e.g. peripheral steroid hormones such as cortisol) and brain structures (e.g. insula, anterior cingulate cortex, and amygdala) involved in development of psychopathic-like behavior will provide clinicians with deeper understanding of mechanisms underpinning this form of psychopathology. Results of neuroimaging study also strongly suggest dysfunction of some brain areas, particularly frontal and temporal lobe structures, in psychopathy. Although the investigation of biological factors in etiology and course of psychopathy antisocial behavior has made a great progress in recent years, research in this field still is in its early phase. Further studies are necessary on interactions neurobiological factors with sociocultural factors and early life experience.

Key words: psychopathy, prefrontal cortex, amygdala, cortisol, neuroimaging, gene-environment interaction

Rola czynników neurobiologicznych w rozwoju cech psychopatycznych u dzieci i młodzieży – przegląd badań

STRESZCZENIE

W pracy tej dokonujemy przeglądu ostatnio przeprowadzonych badań nad neurobiologicznymi podstawami rozwoju psychopatii u dzieci i młodzieży. Typowe dla osób psychopatycznych deficyty występujące w sferze poznawczej i emocjonalnej często połączone są z zaburzeniami w strukturze i funkcjonowaniu obszarów mózgowych, takich szczególnie jak ciało migdałowate czy kora podstawy płata czołowego. Ponadto są dowody, aczkolwiek ograniczone, że z rozwojem psychopatopodobnych cech u dzieci i młodzieży związany jest niski poziom kortyzolu. Przyjęcie szerszej perspektywy, zgodnie z którą zaburzenia psychopatyczne są wynikiem interakcji czynników hormonalnych i uszkodzenia określonych struktur mózgowych, może pomóc klinicytom w głębszym rozumieniu tej formy psychopatologii. Wyniki badań z zastosowaniem metod neuroobrazowania także potwierdzają obecność u psychopatów dysfunkcji pewnych obszarów mózgu, szczególnie w obrębie płata czołowego i skroniowego. Pomimo iż badania nad rolą czynników biologicznych w zaburzeniach antyspołecznych osiągnęły w ostatnich latach duży postęp, to nadal znajdują się one w fazie początkowej. W związku z tym w przyszłych badaniach należy zwrócić uwagę na interakcję czynników neurobiologicznych z czynnikami społeczno-kulturowymi oraz wczesnymi doświadczeniami jednostki.

Słowa kluczowe: psychopatia, ciało migdałowate, kortyzol, neuroobrazowania, interakcja geny – środowisko

Introductory remarks

During the developmental process most of children behaves badly from time to time. Among them there are children who show extreme level of so called “bad behavior”, e.g. they constantly lie, steal, use violence, fight others, etc. They are called “children at risk” for developing such serious forms of disorders as delinquency or antisocial behavior. Professional literature describes some risk-factors associated with these types of psychopathology. They constitute two big groups: 1. biomedical factors (e.g. genetic factors), 2. psychosocial factors (e.g. individual personality traits, familial factors). In case of adult and adolescent persons, a specific constellation of personality traits called “psychopathy” predisposes them to criminal and antisocial behavior. Recent research studies have shown that some basic traits of psychopathy also can be measured in preadolescent children [15]. Early diagnosis of psychopathic traits in children can be very beneficial from developmental point of view because it can be used in prevention of antisocial behavior. Research studies in this field can provide also a deeper understanding of an essence of psychopathic traits in children and the role of biomedical and environmental factors in their development over time.

This paper is intended to provide a basic neuroanatomical framework which would be helpful in interpretation of the range of normal and psychopathic phenotypes, especially in relation to children and adolescents. The analysis of recent professional literature reveals some important differences in opinions. Social scientists (e.g. psychologists, cognitive neuroscientists, psychotherapists) hold opinion that normal and disordered behavior (including psychopathic behavior) falls under control of environment. On the other hand, neuroscientists (e.g. specializing in genetics, neuroanatomy, or neurophysiology) are convinced that behavior is controlled by genetic and neurophysiological factors. Second half of twenty century was a period of dominance by the environmental scientists, but since about two decades we are witnessing a shift toward development of more genetically oriented theories. The truth, as usually, falls in the middle: both genetic and environmental factors interact to form the basis for behavior, both normal and disordered.

Development of psychopathic traits in children

Psychopathy is still understood as a constellation of personality traits and behaviors that are nega-

tively valued. People diagnosed as psychopaths are described as a callous-unemotional persons who are aware of their offenses but lack remorse and guilt. They also avoid personal responsibility for their wrongdoings. Some of them possess superficial charm and use it in order to make “a good impression” on others. Among other traits it should be mentioned their ability to lie with great conviction and heightened level of intelligence [20]. The mental health professionals do not classify psychopaths as “insane” because they do not have a distorted sense of reality and are rationale and aware of their actions. If psychopathy is not associated with a specific mental disorder, it is regarded as an independent constellation of distorted personality traits and behaviors. Although development of psychopathy is observed usually in individuals who experienced difficult childhood, it should be remembered that many people who were raised in disadvantageous life conditions do not become psychopaths. On the other hand, there are many psychopaths who were raised in favorable and nurturing family environments during childhood years. In such situation some scientists argue that such factors as the presence of disturbed parents, parental alcoholism, lack of supervision and inconsistent discipline are strongly related to development of antisocial behavior than psychopathy itself [5]. Thus psychopathy cannot be regarded as an effect of environmental influences only, but must be other factors that shape its development.

Role of genetic factors

Genetically focused research studies of child and adolescent psychopathic disorders give us a possibility to enrich the current knowledge and thus to provide a relevant information for prevention and treatment. Also taking into account a genetic data helps us in better understanding of development of psychopathic traits as a potential risk factor for antisocial behavior. In our paper we shortly review the genetics findings with regard to child and adolescent psychopathy related to such kinds of research methods as twin studies, molecular genetics studies, gene-environment interplay research, etc.

The twin studies

This kind of studies could be regarded as a form of natural experiment. They are based on analysis of genetic connectedness between identical and fraternal twin pairs in order to estimate the contribution of genetic and environmental factors to individual differences. The main assumption of the twin study

method says that if identical twins, sharing 100% of their genetic material, are more similar than fraternal twins on a trait, it means that this trait is genetically influenced. Another words, identical twins' genetic similarity is twice bigger than that of fraternal twins who share only 50% of genetic material. If identical twins are not fully similar on a trait, it means that non-shared environmental influences are responsible for a difference between them.

Professional literature contains various types of studies on genetically influenced predisposition to antisocial behavior and psychopathy. For example, Rhee and Waldman [48] in their comprehensive meta-analysis of 51 twin and adoption studies concluded that about 41% of the variance of antisocial behavior is due to genetic factors, 16% is due to shared environmental factors, and 43% is due to non-shared environmental factors. In another study on stability of antisocial behavior from childhood to adolescence it was found that it is strongly genetically influenced [53]. It might be interesting that the heritability of psychopathic traits indicates moderately strong influences of genetic and non-shared environmental factors [58]. Similar findings were found in earlier study carried out by Blonigen and colleagues [7], but in this case genetic effects explained 29–56 % of variation of psychopathic traits.

The most twin studies that examined the etiology of child and adolescent psychopathy were performed in the USA, the United Kingdom and Sweden. For example, in their study on 398 adolescent male twin pairs Taylor and colleagues [54] have found that genetic effects accounted for 40% of the variation of such psychopathic traits as callous-emotional and impulsive-antisocial characteristics. Another big study was carried out by Larsson, Andershed and Lichtenstein [32]. It included 1.100 pairs of 16-year-old male and female twins. The aim of the study was to examine the heritability of three psychopathic characteristics: callous-unemotional trait, grandiosity-manipulation and impulsivity-irresponsibility. Analysis of results has shown that for grandiosity-manipulation influence of genetic factor was estimated at 51%. Almost all of the remaining variance was explained for non-shared environmental effects, while the shared environment influence seemed to be minimal.

It should be mentioned that genetic factors show moderate to strong influence on various dimensions of psychopathic characteristics in children and adolescents. The influence of non-shared environmental factors is usually moderate, and in case of the shared environmental factors it is weak or – in

some studies – it was not detected. These findings do not preclude the fact that some factors such as the shared environment affect the development of psychopathic-like traits in children through the process of gene-environment interplay.

Molecular genetic studies

Usually the molecular genetic studies undertook in this field of research are focused on the role of so called “candidate genes”, genes that might be connected with a specific personality trait. Respective research studies are using a case-control design in order to compare allelic frequencies both in unrelated affected and unaffected subjects in the studied population. When an allele located in a gene occurs significantly more frequently in the affected group of subjects than in the unaffected, it means that it is associated with certain personality trait. Alas, there are only few studies on role of candidate genes in development of psychopathic-like traits. The results of these studies should be regarded as limited because of relatively small numbers of subjects. For example, Hoenicka and colleagues [23] have found a dependence between psychopathic traits and specific allelic type of cannabinoid receptor type 1 and fatty acid amide hydrolase. It should be emphasized that molecular genetic research on psychopathy is in its beginning stage, whereas much attention has received research on antisocial behavior. In the research on a genetic predisposition to antisocial behavior it was found that an important role play the genes regulating serotonergic neurotransmission, especially monoamine oxidase A (MAOA) [34].

The MAOA gene appears in some variants. The MAOA-H – high-activity allelic variant – is associated with lower concentration of intracellular serotonin, while the MAOA-L - low-activity variant – is associated with lower concentration of that substance. New evidences supplied with results of recent studies suggest that genetic predisposition to antisocial behavior conferred by the MAOA-L variant may be revealed only in case of coexistence of a disadvantageous environmental factors such as child maltreatment and family violence [23]. Existence of the genetic determinants of individual differences in antisocial behavior does not mean that there are genes for antisocial behavior. In this case the influence of genes is much more complicated. In fact, the genes code for a certain types of proteins that influence such traits as neurocognitive properties of an individual. It results in increasing of vulnerability for antisocial behavior. It also means that genetic predisposition alone may be insufficient for evoking antisocial behavior when an individual is

reared in favorable environmental conditions. Other words, the genes take part in creating a kind of the neural “fingerprint”, which is ready to transform into a disorder in disadvantageous environmental factors.

Despite of some evidences pointing toward a direct risk of genetic factors for psychopathy, in fact, this risk rises substantially when genetic factors act with coexistence of environmental factors. This notion is supported by results of recent studies indicating that antisocial behavior in genetically predisposed children may be evoked by a neglect and negative parenting [33]. In an earlier studies it was observed that the gene-environment interaction has a reciprocal character: genetically determined child predispositions evoke negative responses in parents (e.g. in form of maltreatment or aggression), that in turn fosters the development of antisocial behavior [40]. In case of psychopathic-like traits, the process of gene-environment interaction has not been explained sufficiently from the point of view of the behavioral genetics yet. Nevertheless, there are some data indicating that children with such psychopathic-like characteristics as callous-unemotional traits may respond differently to parenting practices than other (i.e. non-psychopathic) children [22].

The research studies on genetical factors influencing development of child and adolescent psychopathy are still scarce and require to consider a multiple analysis of factors involved in the genes-brain-behavior pathway. This new direction of research is very important from prevention and treatment points of view.

Role of other neurobiological factors

The search for neurobiological basis of psychopathy includes neurological, neuropsychological, psychophysiological, brain imaging and hormone studies. Correct understanding of the interaction between biological factors causing neuropathologies associated with psychopathic behavior requires some basic explanations. A simple explanation for the role of biological factors in development of violent and antisocial behavior is that in individual has occurred a substantial damage to the orbital cortex and adjacent parts of the prefrontal and anterior temporal lobe. As it is known, the orbital cortex is a part of the prefrontal cortex that it is located at the base of the frontal lobe. It should be mentioned that other parts of brain (e.g. the frontal pole, ventromedial prefrontal cortex, ventral anterior cingulate cortex, and the anteromedial temporal lobe structures such as the amygdala, temporal tip, anterior parahip-

pocampal gyrus and hippocampal area) are also a subject of neurological studies on antisocial and psychopathic behavior. In case of the orbital cortex, this structure – among other functions – is involved in social interactions, inhibition of impulsive behavior, ethics, morality, reward and punishment, regret, and planned behavior. Also other adjacent regions such as the anteromedial temporal lobe, including the temporal tip, amygdala, and parahippocampal gyrus, are playing an important role in the etiology of antisocial disorders. The problem it is not simply that these areas are badly damaged, but that the circuitry connecting these areas with each other and with several important regions, are either interrupted by mechanical or toxic damage, or dysregulated by some endogenous factors. To this group of factors may belong abnormal neurotransmitter systems, stress hormones, and other gene products that may be present prior to birth and childhood, but only manifest themselves with later neural and endocrine development and are affected by environmental factors.

Neurological studies

Since a long time we know that brain damage being a result of an external or internal factors (e.g. neurodegenerative disease) belongs to neurological conditions which can cause pathological changes in personality. As a classical example can serve a story of Phineas Gage, a construction worker, who suffered a severe damage of prefrontal cortex (PFC) and subsequently developed a total change in his personality becoming a psychopath [10]. Relation between damage of the PFC, especially its ventromedial region, and psychopathic-like traits was confirmed in many studies. To a typical characteristics following the damage of the frontal lobe belong disturbances in emotion regulation, lack of empathy, poor planning, impulsivity and disinhibited behavior. In situations of making moral judgments patients with the PFC damage tend to take actions that involve highly aversive harm to somebody. This result suggests that the PFC takes a crucial part in emotion processing what is important for specific types of moral judgment [29].

Another group of neurological patients, individuals with frontotemporal dementia (FTD), also exhibits symptoms of psychopathic-like traits. The FTD is a progressive neurodegenerative disorder that causes a substantial damage in the frontal lobes, the temporal lobes, or both of them. Individuals suffering because of the FTD manifest psychopathic-like traits such as lack of empathy, violation of moral and legal norms and disregard for the needs of other

people. Patients with the FTD demonstrate a similar pattern of moral decision-making as it is present in individuals with the PFC damage [29].

Cognitive and emotional processing deficits typical for psychopaths are associated with abnormal structure and function of the amygdala. Patients with damage of the amygdala demonstrate some impairments of cognitive processes that are similar to psychopaths, e.g. difficulties with recognizing facial expressions [1]. It does not mean that individuals with damaged amygdala closely resemble the psychopaths. It rather seems that in psychopathic persons most of the amygdala functions are not seriously disordered, but only slightly impaired, what suggests that amygdala-related deficits observed in psychopaths have its specificity.

Neurodevelopmental factors

Some research studies support a presumption that psychopathy might represent a form of neurodevelopmental deficit. In this kind of studies it was evidenced that brain damage occurred in an early life period have effected in psychopathic-like traits in later years. For example, Anderson et al. [2] found that patients with the PFC damage acquired before the age of 16 months developed antisocial and irresponsible behavior and also a deficit of empathy. These psychopathic characteristics were displayed more severely than those observed in individuals who suffered impairment in adult period of life. The authors concluded that normal structure and function of the PFC region is an important condition for moral development of children. In cases when this brain structure is damaged in an early years of life, the process of moral development may be disturbed. Results of such studies demonstrate how brain damages acquired early in life may disrupt emotional, social and moral development in children.

In recent years psychopathy is also associated with cognitive and intellectual dysfunctions, such as the language abilities. For example, psychopathic persons make more errors while processing words with a negative emotional valence. Also they make more errors than non-psychopathic people, while identifying abstract words and understanding an emotional metaphors [26]. Other studies using the Iowa Gambling Test suggest existence of orbitofrontal deficits in psychopathic individuals [39]. Similar neuropsychological impairment related to disordered behavior have been found in studies performed in groups of children and adolescents with psychopathic-like traits. For example, psychopathic adolescents showed positive avoidance learning deficits that indicate dominance of reward in this

group [50]. Such findings are consisted with the results of the studies performed on groups of adult psychopaths, and support an idea about a specific neurodevelopmental trajectories connected with psychopathic traits and behavior.

Psychophysiological factors

Most of the psychophysiological studies on psychopathy have assessed functioning of autonomic and central nervous systems at baseline level or in response to emotional and neutral stimuli. Researchers were using various kinds of measurement, e.g. electrodermal, cardiovascular, and electrocortical indices.

As it is widely known, electrodermal activity is totally controlled by sympathetic nervous system (SNS). It reflects both arousal and responsiveness. Recent studies have shown that psychopathic persons, while compared to non-psychopathic, are electrodermally less responsive in situations when they anticipate and react to aversive stimulus [36].

Some studies were concentrated on a disturbed startle reflex reaction in psychopathic individuals on emotional (fearful, unpleasant) stimuli. It was found that in control group of subjects, presentation of a pleasant stimulus attenuated the startle response and this response was potentiated when subject was confronted with an unpleasant stimulus. In psychopathic individuals the startle response was not potentiated when they presented with an unpleasant stimuli (e.g. a fearful picture). It may be regarded as a result of emotional information processing deficits in psychopaths [43].

Studies on startle reflex and electrodermal reactivity to aversive and stressful stimuli have revealed a diminishing autonomic reactivity in psychopaths. Those findings are compatible with theories paying attention to insensitivity to punishment and reduced capacity for fear in psychopathic people. This insensitivity is related to deficits visible in psychopaths in their emotional relations with other people. Abnormal autonomic reactivity was found also in adolescents with psychopathic-like traits, especially with callous-unemotional characteristics [16]. It might be interesting that abnormal electrodermal response (i.e. a longer half-recovery time) to aversive stimuli in young children is regarded as a factor predisposing them to development of psychopathic-like disorders in later years [19]. These findings are confirmed with results of studies also on aggressive children and youth. For example, aggressive children from ages 3 to 8 years show a significant decrease in fear conditioning what could be an effect of retarded maturation of the amygdala [17]. This

kind of research findings gives us an evidence for an early psychophysiological predisposition to the development of psychopathic-like traits and behavior.

Hormonal factors

Another group of research studies explored a relation between psychopathy and some basic hormones, e.g. testosterone and cortisol. Testosterone is produced by the hypothalamic-pituitary-gonadal axis and influences, among others, reward sensitivity and fear reduction. It is suggested that some main characteristics of psychopathy such as reduced fearfulness, hyporesponsivity to stressors and reduced sensitivity to punishment are an effect of increased testosterone level [57].

In some studies a decreased level of cortisol was found in psychopathic individuals. Subjects scoring higher on psychopathy measurement showed lower cortisol levels than non-psychopathic persons [8, 25, 41].

Since a long time it is hypothesized that testosterone is involved in aggressive and violent behavior. Alas, in recent years only a few studies explored the connection between levels of testosterone and psychopathy. For example, it was found that level of testosterone is positively associated with antisocial behavior of psychopaths and their lifestyle. Significantly higher levels of testosterone were found in young offenders who exhibited such symptoms as breaking the law, difficulties in school or work, marital conflicts, drug and alcohol abuse, and aggressive behavior [9, 30, 38]. Some researchers presume that decreased level of cortisol and increased testosterone are responsible for emotional deficits observed in psychopaths [57]. As it is evidenced, testosterone and cortisol have mutually antagonistic properties. Namely, cortisol decreases production of testosterone and inhibits its effects, while the testosterone inhibits activity of hypothalamic-pituitary-adrenal axis and, as a consequence, decreases the production of cortisol. In the experiments carried out by van Honk and colleagues [56] it was shown that injected testosterone reduces fearfulness in subjects and promotes responding to angry faces presented on pictures. These findings have an important meaning because they show how by manipulating the balance between levels of testosterone and cortisol it is possible to make a significant changes in an individual's decision-making behavior. The differences in the hormone level can be observed in adolescents with psychopathic-like characteristics. For example, a low cortisol level was found in youngsters with callous-unemotional traits which belong to basic symptoms of psychopathy [35]. It is hypothesized that a lower

levels of cortisol in early childhood may negatively influence the social development of an individual by decreasing its responsivity to stressors and fear of aversive stimuli, such as punishment or strong parental control. It should be remembered that levels of testosterone change significantly during time of puberty, so the association between psychopathy and this hormone may vary with age. Nevertheless, hormones can affect patterns of behavior by influencing the functioning of main brain regions.

Neurotransmitter factors

By neurotransmitters we understand a chemical substances that transmit impulses across synapses between neurons. They are secreted from the pre-synaptic site and make communication possible from one neuron to another. The kind of message, which is send, depends on the type neurotransmitter released into the synapse. It should be emphasized that research studies related to the role of neurotransmitters in psychopathy are in their early stage. Nevertheless, some of the studies have shown a significant reduction of serotonin in psychopaths [13]. Another studies suggest that behavior disorders appeared in psychopaths are associated with both serotonin and dopamine levels. It was evidenced that the aggressive behavior in psychopaths is related to the ration of cerebral fluid homovanilic acid –HVA (a metabolite of the dopamine) and 5-hydroindol-acetic acid – 5-HIAA (a metabolite of the serotonin) [52]. This kinds of results help us to understand a roots of aggressive and disordered behaviors that are often manifested by psychopathy. Also these findings explain development of such traits typical for psychopaths as sensation seeking, poor behavioral control and irresponsibility. Generally speaking, studies on neurotransmitter abnormalities are very important because their results can be used for developing more effective medical interventions (e.g. in production of drugs which could be helpful in managing some of the traits and behaviors related to psychopathy).

Neuroimaging research

Although psychopathy is clinically well-documented, its neuropsychology remains only partly explained and understood. In recent years, an increasing number of neuroimaging studies have been performed in order to identify the brain anomalies associated with psychopathy. The results of such studies could have significant importance for the psychopathological picture of psychopaths, as well for developing a neurobiological models of human

social behavior in “normal” people. The structural and functional neuroimaging studies of psychopathy, recently carried out, are characterized by variability in their results.

While the developmental course of antisocial and psychopathic behavior is heterogeneous, studies have identified some risk factors for negative outcome. Especially those children who exhibit strong conduct disorder (CD) symptoms before the age of 10 years tend to exhibit high levels of aggression throughout adolescence and are at risk of developing the psychopathic-like disorders until adulthood [49]. They are called “early starters” and seem to have a great load of biological risk factors for antisocial and psychopathic development and for this reason have been investigated intensively in recent years with modern research tools such as neuroimaging [21]. Recently developed neuroimaging techniques such as magnetic resonance imaging (MRI) provide a unique chance to investigate structural and functional abnormalities that accompany neuropsychiatric disorders in childhood. As it was mentioned, the antisocial and psychopathic behavior in children and adolescents is notably less studied than in adults.

Among several different types of neuroimaging techniques such as positron emission tomography (PET), single photon emission tomography (SPECT) or computer tomography (CT), MRI is especially suitable for the investigation of children. Its usefulness is based on fact that it provides pictures with high spatial resolution, is not invasive and does not require radioactive substances or ionizing radiation [42]. In addition to the assessment of structural brain data using MRI, functional MRI (fMRI) offers the possibility of demonstrating indirectly the association between the involvement of certain brain areas in defined cognitive and emotional processes [18]. Occurring changes of activation can be displayed in real time and *in vivo*. Advantages of brain imaging make that it is an important factor of biological research on antisocial behavior and psychopathic personality. Nevertheless, in the last decade neuroimaging studies focusing on children with psychopathic-like disorders are rather scarce. In such circumstance the most findings on antisocial behavior and psychopathic disorders still derive from adult samples, because the affected adults often suffer from other types of comorbid psychopathology, as alcohol or drug abuse.

Among structural brain imaging studies most have focused on the PFC, and findings suggest that psychopathic people exhibit impairments in this region. For example, Raine et al. [46] showed

significant prefrontal grey matter volume reductions in patients with antisocial personality disorder who also scored high on psychopathy. In similar research study, Yang et al [59] found significant prefrontal grey matter reductions in adult criminals with psychopathy, compared with control subjects. These and other studies suggest that reduced grey matter volume in the PFC of psychopathic people is a factor contributing to the poor decision-making, emotional dysregulation, and impaired moral judgment. Another findings linking structural impairments in brain regions beyond the PFC with psychopathy has also been found. For example, Laakso et al. [31] found reduced posterior hippocampus volumes in antisocial alcoholics with high scores on psychopathy measure. Psychopathic persons also show volume reductions in the bilateral amygdala, especially the basolateral and superficial nuclei groups. As it was already emphasized, the deficits in the amygdala-hippocampal complex are associated with emotional disorders including shallow affect and lack of remorse in psychopathic people, as well as social dysfunctions including pathological lying and superficial charm. In his later studies, Raine et al. [47] found significantly increased callosal white matter volume, increased callosal length, and increased functional inter-hemispheric connectivity in psychopathic people. Callosal volume was significantly related to the deficient affect factor of psychopathy, and – to a lesser extent – the impulsive-irresponsible factor, but not the arrogant-deceptive factor. Overall, findings indicate that structural impairments, particularly in the amygdala, hippocampus, and corpus callosum, may contribute to the emotional deficits found in psychopathic individuals.

In their study with single-photon emission computed tomography Soderstrom et al. [51] found significant negative correlations between psychopathy scores (particularly the interpersonal factor) and fronto-temporal perfusion. It was evidenced that, functionally, psychopathic people show abnormal activation in the fronto-temporal circuit. Also Kiehl and colleagues [27] in their fMRI study on performance of a semantic task in group of psychopaths, found that the subjects failed to show the appropriate neural differentiation between abstract and concrete stimuli in the right superior temporal gyrus, left ventrolateral PFC, middle temporal cortex, and anterior cingulate cortex.

Similar results were obtained in recently performed structural MRI studies that used voxel-based morphometry (VBM). An automated voxel-wise method for the detection of regional differences in

grey or white matter [3], have provided confirmatory evidence for neural deficits in brain structures that showed functional abnormalities in fMRI studies. For example, two VBM studies in youth with conduct disorders showed decreased grey-matter volume in mesial temporal lobe structures, including the amygdala, and a significant association of these grey matter deficits with the severity of conduct problems such as antisocial and aggressive behaviors [24]. Evidence from recent fMRI investigations suggest a crucial involvement of the anterior insula in the experience of such emotional conditions as empathy [12]. Some authors of this kind of studies emphasize that there is a need for further research to explain deeper understanding of previously obtained results.

Neuroimaging studies is obviously a very promising field of research into neurobiology of psychopathy and antisocial behavior. There are some possible strategies in this field. One of them is based on isolation of subgroups of subjects with a distinct phenotypical characteristics concerning the mechanisms underlying a specific type of disordered behavior. Second strategy could be aimed at larger study populations that may comprise various subtypes of antisocial behavior and also allow for genotypic differentiation. As a third strategy could be a longitudinal studies performed in a large community-based populations, both clinical and non-clinical, what would be helpful in understanding the development, course and prognosis of antisocial behavior and psychopathic-like traits in children and adolescents. In this regard, neuroimaging may provide a valuable information for prevention and treatment of that kind of psychopathology.

Neurobiology of fear-processing deficit in psychopaths

It is widely known that one of the most typical characteristics of psychopaths is their lack of fear expression. This should be considered as unnatural phenomenon because fear belongs to basic human emotions. In the past years a big number of researches have been conducted in order to explain why psychopaths are devoid of fear. Overwhelming evidences show on an important role of neurobiological mechanisms involved in fear-processing [14].

Since about twenty years we know that psychopaths significantly differ from non-psychopathic population in respect to the startle reflexes. For example, it was revealed that psychopaths, unlike people without this disorder, react with constant heart rates and blinking patterns while watching

both neutral and unpleasant images [43]. The conclusion could be deduced that psychopaths are not emotionally affected by unpleasant stimuli shown on the pictures and don't demonstrate a visible symptoms of fear. Several years ago a series of experiments were carried out focused on assessment of the brain activity in psychopaths also during the presentation of pictures differing in degree of unpleasantness. Examined persons were simultaneously under painful pressure. The results showed that some parts of the emotion-related brain circuit were overactive while other parts of the same brain circuit were significantly underactive. This unusual brain activation patterns in psychopaths show that they don't exhibit normal physiological responses to fear [4].

In other research studies it was found that psychopaths also show abnormal physiological responses to such stimuli as frightening sentences. When they were listening to such sentences their muscular responses did not exhibit any tension, remained unchanged, while in other people the muscles unconsciously become tense. This finding shows that psychopaths interpret this kind of stimuli in different way at an emotional level. It is another evidence that they don't react to fear in the way which is typical for most of the people belonging to the general population [45].

Another interesting characteristic observed in psychopaths is a difficulty with correct interpretation of facial expression of emotions in others. Many research studies have indicated that even such basic emotions like sadness or fear are misinterpreted by psychopaths as neutral. At the same time they have no difficulty in identifying happy facial expressions. This suggests that while psychopaths are able to experience some positive emotions and recognize them in other people, they display a fear-processing deficit that makes them difficult to experience fear themselves and to recognize it in the facial expression of other persons [14]. Some researchers are convinced that on the intellectual level psychopaths are able to recognize a differences between a words that may elicit fear and a neutral ones but this is meaningless for them. As a result they don't use an emotional cues for guidance of their personal judgments or behaviors [37].

Results of some recently carried out studies suggest that abnormal physiological responses to fear in psychopaths are due to the dysfunction of such neural structures as the amygdala and orbitofrontal cortex (OFC). For example, the amygdala – being located in the temporal lobe of the brain – is connected with disordered startle reflexes and

mistaken recognition of facial expression of emotions, especially such as the fear. In comparison with the amygdala, the OFC – being part of the frontal lobe – is associated with the anticipation of punishment and reward. In normal people the anticipation of negative consequences of their behavior evokes a fear which prevents them from doing something wrong. In psychopaths the dysfunction in the OFC results in failure to experience fear. Additionally, some findings prove that the OFC dysfunction is associated with heightened level of reactive aggression which is another characteristic traits of the psychopaths [6].

The fear deficit presents in psychopaths in professional literature is explained through different concepts. One of them is the integrated emotions systems (IES) model. The IES concept is based on research studies that take into consideration the amygdala dysfunction in psychopaths and attempt to explain how this dysfunction results in fear deficit. According to the IES concept an amygdala-based dysfunction restrains the individual's ability to be successfully conditioned in the process of upbringing. As it is known our fearful and sad expressions are a kind of unconditioned responses to negative stimuli appeared in our surrounding, but the association between those expressions and resulting actions (e.g. escape) has a conditioned nature. People with amygdala dysfunction, like psychopaths, fail to learn and identify the connection between fearful and sad experience and external expressions caused by those emotions [14]. Fear-processing deficits have even more serious consequences on emotional and social development of an individual. For example, they hinder the process of moral and social development in children and adolescents. In normal individuals moral and social development is achieved through the implementation of rewards and punishments. When they anticipate a punishment and experience a fear, this results in the inhibition of forbidden behavior. Thus in most people, since an early childhood, punishments form a strong connection between undesired actions and fear or anxiety what inhibits a tendency for prohibited behavior. Because of a lack of fear in psychopaths the association between misbehavior and punishment is weak, so they are more prone to engage in prohibited actions than normal individuals [6].

Final remarks

At the present time we still do not know exactly what causes the pattern of neurobiological impairments observed in antisocial and psychopathic chil-

dren and adolescents, although it is clear that genetic and other neurobiological factors are involved. An important part of research studies suggests that disadvantageous psychosocial conditions affects brain development (e.g. because they trigger an expression of particular genes). Neuroimaging research, especially the fMRI studies, support the notion that prefrontal cortex and amygdala dysfunction may be a key neurodevelopmental etiological factor in understanding callous-unemotional and other traits typical for psychopathy. It shows the potential utility of neuroimaging techniques in advancing our neuroscientific knowledge about the developmental nature of disorders such as psychopathy. Because complex traits and behaviors are mediated by anatomically interconnected neural circuits with gray and white matter components, future studies need to look at both the structural and the functional neural correlates of key traits, symptoms, or behaviors in order to advance our neuroscientific knowledge on development of psychopathic-like traits and behaviors in children and adolescents. By studying development of psychopathic-like traits earlier in life, it is more likely that we can develop more effective prevention and treatment efforts based on a sound and coherent theoretical causal basis. Also much more work is needed on the role of genetic-environmental influences on the development of psychopathic traits and antisocial behavior in early period of life. If psychopathic traits and serious antisocial behavior are, in a great part, neurodevelopmentally determined, successful prevention and intervention efforts would be more effective if they begin in early childhood, infancy, or even prenatally.

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