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Neurobiology of creativity: is there any association with bipolar mood disorder?

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Summary

Creativity can be defined as a production of action or idea both original and useful, and its effective implementation. Such features of brain functioning may have an evolutionary advantage, increasing chances of survival and achieving reproductive success. Creativity occurs already in some animals but to the greatest extent is present in contemporary humans. The number of genes implicitly associated with creativity is greater in *Homo sapiens* compared with *Homo neandenthalesis*, in which it exceeds the number occurring in chimpanzees. The brain structures most essential for creativity involve the frontal and temporal lobes, the default mode network and the cerebellum, and the main neurotransmitter system is the dopaminergic one. Psychological processes associated with creativity include unusual mode of thinking and increased motivation driven by mood.

In the field of psychopathology, most data make a case for the association of creativity with bipolar mood disorder (BD). Among writers, artists and their families, there is an overrepresentation of BD and cyclothymic personality. In BD, unusual thinking is frequent, and enhanced creativity is usually associated with elevated mood. The studies of Nancy Andreasen, Kay Jamison, Terence Ketter, Tiffany Greenwood, and own investigation in this area are presented. The results of many analyses point to a shared vulnerability to creativity and BD. In many outstanding artists, including Polish ones, we observe the full clinical expression of the illness.

Key words: creativity, bipolar mood disorder

Introduction

Creativity has been a subject of interest for philosophers since the dawn of time, and from the 19th century, for psychologists and psychiatrists as well. In recent decades, some progress has been made as to the neurobiology of this matter and its relationship to psychopathology, especially to bipolar mood disorder (BD). This article attempts to present the results of this new research.

Definition of creativity

The term "creativity" comes from the Latin verb *creare* meaning to create, however, it is also related to the verb *cresco* meaning to grow. In Polish language, similar to *kreatywność* is the term *twórczość* [1]. In 2010, Kamplylis and Valtanen [2] reviewed 42 definitions of creativity. The majority of them pertained to a generation of new or original products and its adequate application. The authors also pointed out a possibility of either positive or negative creativity. For the purpose of this paper, the working definition of creativity was adopted as a production of action or idea both original and useful, and its effective implementation.

Creativity in the process of evolution

Creativity as a feature of brain functioning may have an evolutionary advantage, increasing chances of survival and achieving reproductive success. Paulo Cabeça from the Portuguese University of Evora considers creativity as a biological weapon, used also by some animals, e.g., birds or primates. These animals discover a method of problem-solving that facilitates their functioning and survival, and subsequently, other representatives of their species learn through observation. In these processes, the main role is played by the activity of the cerebellum [3].

In 2022, the international research team led by Robert Cloninger, known as the author of the biological model of temperament, compared the genomes of the chimpanzees, *Homo neanderthalensis,* and *Homo sapiens.* It turned out that the number of genes associated with self-control and self-awareness, so indirectly with creativity, in *Homo neanderthalensis* was intermediate between chimpanzees and modern human, and 267 genes occurred uniquely in *Homo sapiens*. Nearly all pertained to self-awareness, were not protein-coding, and were so-called long-noncoding RNAs. The authors of the paper reckon that these genes may have arisen in modern humans by positive selection for creativity, prosocial behavior, and longevity. The overexpression of these genes was shown in brain areas associated with self-awareness and creativity that are phylogenetically recent regions of the neocortex in frontal, parietal, and temporal lobes, as well as in cortico-thalamo-ponto-cerebellar and cortico-striatal loops [4]. Reproductive success associated with creativity was postulated in the studies of artists at the beginning of the 21st century, showing that creative activity can function as a factor of attractiveness for sexual partners and correlate with a greater number of partners [5, 6].

Creativity – association with the features of thinking and information processing

As early as the 1950s, an American psychologist, Paul Guilford (1897–1987), put forward a hypothesis linking creativity with so-called divergent thinking [7]. The term divergent or otherwise lateral thinking denotes the process of creating multiple (crea-

tive) ideas or solutions to a problem. Whereas, in the 1990s, a British psychologist, Hans Eysenck (1916–1997), proposed a concept presuming that a significant feature of creativity is "psychotic" thinking which is also characteristic of schizophrenia spectrum disorders [8]. For the assessment of creativity, Eysenck used the *Barron-Welsh Art Scale* (BWAS) elaborated in 1963 by a psychologist, Frank Barron, from the University of Berkeley, based on psychoanalytic premises [9]. This scale was also used in psychiatric investigations on creativity carried out in the 21st century.

A feature of information processing with a tendency to enhance creativity, and also a proneness to psychosis is an attenuation of so-called latent inhibition (LI). This means to notice the stimuli from the environment that were previously evaluated as insignificant. This could explain why creative persons can notice something that is locked to others and have access to a wider range of stimuli at an early stage of processing, which increases their chances for original thinking. Shelley Carson, an American psychologist from Harvard University, in an article published in 2003, using the experimental methods of LI measuring, showed in a group of 86 students that persons with high creativity had significantly lower results of LI compared with persons with low creativity. She also found that a high intelligence quotient (IQ) was a facilitating factor for mastering the low LI in creative achievements [10]. During the next years, Carson continued her thoughts on creativity and proposed a training of creativity in her book *Your Creative Brain* published in 2010 [11]. Later, she declared herself a supporter of the notion of shared vulnerability to creativity and psychopathology, which includes such features as cognitive disinhibition, referring to previously studied LI, a tendency to novelty seeking, mood lability, and increased neuronal connections [12, 13].

Schizotypy

The phenomenon of schizotypy may reflect the aspects of thinking and information processing described above. Schizotypy is a disorder belonging to the schizophrenic spectrum characterized, among others, by a tendency to eccentricity, magical thinking, and unusual experiences, however, retaining control over own cognitive processes. Many studies were performed indicating a connection between schizotypic features and increased creativity, some of them are presented below.

In 2006, the results were published of 107 students and staff members, among whom 53 came from the reputable Department of Visual Arts, University of London, and 54 from other university departments. A number of psychometric scales was used such as a tool for schizotypic features (the *Oxford-Liverpool Inventory of Feelings and Experiences* – O-LIFE), a personality inventory NEO-FFI, a scale of creative personality, an intelligence scale, and a divergent thinking test. The group of visual artists obtained significantly higher scores on three schizotypal scales, as well as on neuroticism, openness to experience, and divergent thinking [14].

In 2014, an on-line research was performed in which the O-LIFE schizotypy questionnaire was completed by about 500 comedians and 350 actors from the United

Kingdom, USA, and Australia. It was hypothesized that comedians, similar to persons with high creativity would obtain higher scores of "psychoticism." The hypothesis was confirmed as the comedians acquired higher results on all subscales of the O-LIFE. Interestingly, they had higher scores both in introversion/anhedonia and in extroversion/impulsivity subscales which may allude to bipolar mood changes [15].

In a paper from 2018, 37 persons with high schizotypy indexes were compared with 41 ones with low indexes. The persons with high schizotypy obtained significantly better results in the creativity tests. Two features mediated higher creativity, namely overinclusive thinking, in other words widening of conceptual boundaries, related in a sense to divergent thinking. The second feature was cognitive inhibition measured by the Stroop interference test [16].

Worthy noticing is a paper by Austrian authors published in 2022, pointing to so-called positive and negative schizotypy, assessed by the O-LIFE. It turned out that the subscale of "cognitive disorganization" correlated with malevolent creativity, inclined toward doing harm to another person [17].

Brain structures associated with creativity

Defining brain structures associated with creativity had several periods. The first assumed cooperation of the parts associated with cognitive functions with brain centers governing motivation. The model presented in 2005 by Alice Flaherty on idea generation and creative drive assumed a dominant role in frontal and temporal lobes and the mesolimbic system [18]. A special role of the prefrontal cortex in the process of creativity was demonstrated in neuroimaging studies. Carlsson et al. [19] measured the regional cerebral blood flow (rCBF) in persons obtaining high or low results in the creativity tests. During the procedure, the subjects performed psychological tests including the test for divergent thinking. It turned out that during tests, the creative group utilized frontal lobes bilaterally, while the persons with low creativity used them only on the one side. Folley and Park [20] investigated the activity of the prefrontal cortex during creative thinking task using near-infrared optical imaging in 17 patients with schizophrenia, 17 persons with schizotypal traits, and 17 healthy controls. The persons with schizotypal traits obtained significantly better results in divergent thinking compared with the remaining ones. In neuroimaging, these persons had significantly higher activation of the prefrontal cortex, especially on the right side, compared with the other groups. The results of both studies also confirm the importance of the integration of both brain hemispheres for creative activity.

Since the mid-1990s, a special area of interest in the context of the creative process is the brain activity during rest, assessed by neuroimaging. Initially, that state was described by the acronym REST (random episodic silent thought), and subsequently as Default Mode Network (DMN), meaning the network of resting state. Anatomically, the DMN involves mainly medial prefrontal cortex, posterior cingulate gyrus, precuneus, and angular gyrus. The neuroimaging studies showed that this network is by no

means idle but manifests the activity, especially when it comes to the integration of thoughts and experiences. Vellante et al. [21] proposed a psychoanalytical perspective of creativity, understood as enhanced activity of DMN in the realm of free associations, which may correspond to the generation of "creative" ideas. Creative persons display higher activity of cortical associative areas during the association tasks. These authors also reckon that besides DMN, the brain structures associated with emotions, such as the amygdala and insula, are taking part in the process of creativity.

Recently, the research was performed using functional magnetic resonance imaging (fMRI) where participants were asked to generate creative ideas in both a uses generation task and a metaphor production task. The generation of creative uses activated bilateral inferior frontal gyrus, medial prefrontal cortex, left supplementary motor area, left angular gyrus, left thalamus, and bilateral cerebellum posterior lobe. The generation of creative metaphors activated the dorsal medial prefrontal cortex and left angular gyrus [22]. The study confirmed a significant role of such DMN parts as the medial prefrontal cortex and angular gyrus, indicating also the importance of cerebellar activity which will be discussed below.

In 2015, in an article by researchers from Stanford University, an important role in the process of creativity was attributed to the function of the cerebellum. The authors elaborated a test of figural creativity consisting of drawing on a tablet a figure reflecting a verb (e.g., levitate, exhale, whisper), during brain imaging by the fMRI. The results of the study showed that the intensity of thinking correlated with the activity of the left prefrontal cortex while the mere creativity – with the bilateral activity of the cerebellum [23]. A commentary to this paper appeared in the journal *Science News* bearing a somewhat provocative title: *Cerebellum may be site of creative spark* [24].

In recent years, an increase in interest in the role of cerebellar activity in the processes of both creativity and art perception has been observed. It is thought that the most important parts of the cerebellum in this respect include posterior areas of the cerebellum with lobule VII with crus I and crus II as well as the vermis. They constitute a fragment of neural circuits involving the prefrontal cortex and the DMN [25]. The researchers from Cracow described emotional disturbances following the lesions of these parts of the cerebellum [26]. A contribution of the cerebellum may confirm a significant role of subconscious processes in creativity, which was pointed out by many researchers.

In 2024, the article appeared in the journal *Cerebellum* postulating a dominant role of the cerebellum (and not the prefrontal cortex) during the recent one and a half million years of human evolution. During this time, the volume of the cerebellum increased thrice. The activity of this organ was crucial for the process of producing stone tools with increasing level of elaborateness, and probably also for speech. Similar to animals, the activity of the cerebellum was also essential for learning by other representatives of our species by imitating [27].

Neurotransmitters and genes

Dopamine is the most important neurotransmitter underlying "psychotic" thinking and elevated mood which are regarded as the factors associated with creativity. It pertains mainly to the dopaminergic routes in the mesolimbic system and cerebral cortex. Dopamine attenuates the process of habituation and causes a sense of enhanced perception and salience to environmental stimuli [28], as well as a weakening of latent inhibition [29]. Increased activity of the dopaminergic system underpins the elevated mood in BD [30].

Molecular-genetic studies using the candidate gene approach indicated an association between polymorphism of the dopaminergic receptor 2 *(DRD2)* gene with overall and verbal creativity [31]. The polymorphism of the neuregulin 1 *(NRG1)* gene was associated with creativity in a person with high intellectual capability [32]. Both genes are implicated in the predisposition to both schizophrenia and BD [33]. A possible contribution of serotonergic system genes such as the tryptophan hydroxylase (*TPH)* gene, in overall, numeric, and figural creativity [31], and serotonin transporter *(SLC6A4)* gene in dance creativity [34] were also shown.

The relationship between creativity and psychopathology

Since antiquity, there has been an ongoing discussion on the relationship between eminent creativity and psychopathology (the so-called mad genius debate). The above-quoted association between creativity and the disturbances of thinking and mood could suggest its relationship to a spectrum of schizophrenia and bipolar mood disorders. Based on the current data it seems that there is a higher probability of an association of creativity with the BD spectrum, however, in some analyses, a connection with the schizophrenia spectrum is also suggested. In the next subchapters, a case will be made for a hypothesis of such connection with BD, arising from, among others, studies of some researchers.

The studies of Nancy Andreasen

Nancy Andreasen (born in 1938) was the long-term chairwoman of the Department of Psychiatry, University of Iowa, and the Editor-in-Chief of the *American Journal of Psychiatry*. She is well-known as an advocate of the positive and negative symptoms of schizophrenia and as the creator of the scales for their measurement [35]. Her book *Brave New Brain* published in 2001 [36] had the Polish edition in 2003 as *Fascynujący mózg* [37]. Andreasen participated in the studies of creativity in two projects called *The Iowa Study of Creative Genius*. The first of them involved 30 creative writers, 30 control persons, and first-degree relatives of both groups. A hypothesis was advanced about a relationship between creativity and psychosis based on information about several famous persons having relatives with schizophrenia. However, it was shown that in the writers and their relatives, a significant preponderance of mood disorders,

especially bipolar, occurred. All groups had high IQs, however, the creative persons and their families did not differ in this respect from the remaining ones, which may suggest that intelligence and creativity are not very closely related [38].

In 2005, Andreasen in the book *Creative Brain* [39] put forward a hypothesis on the relationship between mathematical creativity and a predisposition to schizophrenia, and between artistic creativity and a predisposition to BD. According to her, a tendency to disturbances of the schizophrenia spectrum (personal or familial) occurred in the geniuses who made the greatest mathematical and scientific discoveries, such as Isaac Newton (1643–1727), the originator of higher mathematics, Albert Einstein (1879–1955), the creator of the theory of relativity, and Francis Crick (1916–2004), one of the discoverers of DNA helix [39]. Also John Nash (1928–2015), the Nobel laureate in economics in 1994 for studies in game theory suffered from schizophrenia. His illness was presented in the book and the movie titled *The Beautiful Mind*. However, the research of *The Second Iowa Study of Creative Genius* including highly creative scientists and artists and using neuroimaging, did not show differences in brain functioning between these two groups, therefore the hypothesis was not confirmed. In her further articles, Andreasen pointed at a significant role of the subconscious processes in creativity [40].

The studies of Kay Jamison

Kay Jamison (born in 1946), a professor of psychology, currently working at the Johns Hopkins University in Baltimore, is a co-author, together with a former chief of the National Institute of Mental Health, Frederick Goodwin (1936–2020), of a monumental book *Manic-Depressive Illness*, which had two editions – in 1990 and 2007 [41, 42]. However, the international popularity, to a great extent, she owes to the book *Unquiet Mind*, published in 1996, in which she described with bravado her bipolar mood disorder and lithium treatment [43]. In Poland, this book under the title *Niespokojny umysł* had two editions – in 2000 and 2018 [44, 45]. Whereas earlier, in 1993, appeared her book *Touched with Fire*, which can be regarded as one of the best elaborations on the relationship between the creative process and BD. The subtitle of the book reads *Manic-depressive illness and artistic temperament*, and among the many authors "touched with fire" she talks about George Byron, Robert Schumann, Vincent van Gogh, Ernest Hemingway, and Richard Lowell [46]. Jamison devoted a separate publication to the latter, published in 2017, in the context of his manic-depressive illness and the body of work [47]. In the book *Touched with Fire,* Jamison, with amazing talent, depicts the interlacing of motifs of illness and creativity, illustrated by the fragments of the authors' works. This was facilitated by her education in English literature (such educational background is also of Nancy Andreasen, mentioned earlier). Kay Jamison, apart from the mentioned books, produced several excellent literary works (some of them refer back to BD), therefore, it can be stated that she can make an epitome of a person with BD and outstanding creativity.

Epidemiological studies on the relationship between creativity and bipolar disorder

The results of the epidemiological studies performed by the researchers mentioned above showed that there is an overrepresentation of BD-like disorders in the group of artists and writers [38, 48]. The significantly higher indexes of creativity occurred also in relatives of persons with BD [38, 49, 50]. In 2011, Swedish researchers analyzed the relationship between the illness and practicing a "creative" profession in 300,000 persons with severe mental illness. It turned out that the overrepresentation of such professionals appeared in subjects with BD, their relatives, and the relatives of persons with schizophrenia [51]. In 2013, the authors from Cracow showed that the students of artistic fields had higher scores of creativity measured by the *Mood Disorder Questionnaire* compared to students of technical schools [52].

The eminent specialist in BD, Hagop Akiskal (1944–2021), an American psychiatrist of Armenian origin, is the author of the questionnaire for affective temperaments TEMPS-A (*Temperament Evaluation of Memphis, Pisa and San Diego Autoquestionnaire*). The most characteristic of BD are cyclothymic and hyperthymic temperaments. A preponderance of these temperaments was found in artists and the students of artistic faculties [53], also in a Polish study [54]. According to Akiskal, the cyclothymic temperament is associated with frequent falling in love and a higher number of partners which, in an evolutionary context, may translate into reproductive success [55].

The features of unusual thinking in BD

In the previous subchapters, it was indicated that creativity is associated with the features of unusual thinking. It transpired that such attributes are more prevalent in persons with BD spectrum than in the general population. In a study of 135 patients with schizophrenia, 92 patients with BD and 263 healthy persons, it was found that schizotypal traits were more prevalent in patients with BD than in healthy persons, but lower than in patients with schizophrenia [56]. Whereas in 625 students, a significant correlation was found between the feature of psychoticism and the results of the *How do you think* test measuring creativity and the *Perceptual Aberrations* test pertained to schizotypy, as well as with hypomanic traits [57].

Research performed in recent years brought about another evidence for the association between divergent thinking thought to be associated with creativity, and BD. Japanese authors in a population of 1,558 students found an association between the polygenic risk score (PRS) for BD and the creativity measured by divergent thinking (CMDT) [58]. A significant correlation between BD and divergent thinking was also demonstrated in the meta-analysis of clinical studies [59].

The studies of the Stanford University

The research group of the Department of Psychiatry and Behavioral Sciences, Stanford University, led by the eminent expert of the illness, Terence Ketter (1950–2024), significantly contributed to studies on the relationship between creativity and BD. In this research, Cecylia Nowakowska previously working at the Department of Psychiatry, Medical Academy in Poznan, took part. It was shown that the patients with BD display similar personality features as the persons of high creativity, i.e., higher values of cyclothymia and irritability, increased neuroticism, as well as greater openness and novelty seeking [60, 61]. Moreover, it was demonstrated that both adults with BD and children of persons with BD achieved higher scores on the BWAS creativity scale, compared with healthy control subjects [62, 63]. Summarizing the factors influencing enhanced creativity in persons of BD spectrum, the authors list cyclothymia, assessed by the TEMPS-A, neuroticism, and openness to experience evaluated by the *Neuroticism, Extraversion and Openness Personality Inventory* (NEO), and cognitive intuition estimated by the *Myers-Briggs Type Indicator* [64].

The studies of the Department of Adult Psychiatry, Poznan University of Medical Sciences

The research on the relationship between bipolar mood disorder and creativity was performed on 40 patients with BD and 48 healthy sex – and age-matched persons. Creativity was assessed by means of the BWAS scale and the creativity part of the *Berlin Intelligence Structure* (BIS) scale. Schizotypy was measured by the O-LIFE scale. The obtained results showed that the remitted BD patients achieved better results in creative tests of BIS, had more art, musical, and literary abilities, and higher scores of schizotypy. In the relatives of BD patients, there was a more frequent occurrence of artistic talents and a higher percentage of persons having outstanding substantiated artistic and scientific achievements. In persons with BD, the significance of schizotypy as a mediating factor in creativity was shown [65]. The research was the topic of Paulina Klonowska's doctoral thesis. For that, she received the Wojciech Moczulski's prize at the Polish Psychiatric Association Congress in Poznan in 2010.

The measures of creativity estimated by the BWAS and BIS were also compared between 60 patients with schizophrenia in remission and 45 healthy persons, sex – and age-matched. Patients with schizophrenia obtained lower values in the tests of creativity, which correlated with impairment of executive functions measured by the *Wisconsin Card Sorting Test* (WCST). This was the topic of Amelia Patrzała's doctoral dissertation [66].

The study was also performed on the association between the Val/Met polymorphism of the *BDNF* (brain-derived neurotrophic factor) gene with cognitive functions in BD patients. It was shown that the Val allele of this polymorphism is associated with better efficiency of the prefrontal cortex estimated by the WCST [67, 68]. Whereas

Soeiro-de-Souza et al. [69] stated that manic patients, Val allele carriers, achieved better results in the BWAS creativity test. Since the Val allele of this polymorphism shows an association with the predisposition to BD [70], these observations could make an example of the evolutionary trade-off, where a predisposition to an illness is linked with a tendency to better cognitive functioning.

The studies of Tiffany Greenwood

In recent years, there has been leading research by Tiffany Greenwood, a psychologist from the University of California at San Diego. She made the elaboration on the shared genetic vulnerability to bipolar mood disorder and creativity [71,] and carried out the wide-ranging research in this respect [72]. 135 patients with BD participated in the study, along with 205 healthy persons, including 102 with high creativity. Significant interplays were observed in common features predisposing to vulnerability such as hypomanic personality, cyclothymic temperament, impulsivity, and positive schizotypy. A combination of such features as openness, hypomanic personality, divergent thinking, and reasoning ability made the strongest predictor of creativity.

Creativity and bipolar mood disorder

In addition to a shared vulnerability to creativity and BD, there is a host of highly creative persons with a full clinical expression of the illness. In our country, this has been exemplified by the three great artists suffering from BD who passed away in the 21st century [73].

Wojciech Młynarski (1941–2017), the outstanding poet and songster, was the author of more than 1,000 pieces of work, some of which were iconic during the communist times in Poland. What is more, the messages of many of his musical "pearls" are timeless. In 2011, he wrote a poem titled *The guilt of Tusk* giving a definition: This is a nice catechism of considerable political party. However, he did not foresee that both in the 2023 election campaign and after the elections, the aforementioned person would become an epitome of all evil by the party of the opposing political camp. After 2015, he realized that an escalating catastrophe in our country came near. The frequent reactivating of his song *Let's do our thing* might serve to keep the spirits of the civil society. If he lived to see the 15 of October 2023, he would certainly commemorate it with a beautiful piece of work. Until the end of his life, he was fondly cared for by inconsolable Dariusz Wasilewski, the most outstanding musician among Polish psychiatrists, who outlived him only by four years.

Maciej Zembaty (1944–2011), an excellent poet, songster, and comedian, and also the unsurpassed master of black and absurd humor. Examples of the latter were the songs *In the cadaver dissecting-room* or *The last respect* orchestrated by Fryderyk Chopin's funeral march b-minor. Among his many achievements, I remember a remarkable radio

drama *The Poszepszyński family* which had been broadcasting nearly a quarter of the century. The last two decades of Zembaty's life were marked by frequent episodes of the illness. Their treatment was not satisfactory and the illness made it impossible for an adequate functioning in the last years of his life.

Marek Grechuta (1945–2006), a magnificent songster, poet, composer, and painter. He is regarded as the most outstanding representative of the Polish sung poetry. Similar to the case of two giants of the stage described above, it is impossible to list all songs eliciting in the author of this article amazing emotional experiences in the two last decades of the 20th century. However, Grechuta's long-term psychiatric treatment was not sufficiently effective. This resulted in a significant impairment of his artistic functioning in the last years of his life and probably contributed to his premature death at the age of 61.

Recapitulation

In the past two decades, several novel evidences have been obtained for a connection between high creativity and the phenomenon of BD and its personality dimensions. It is assumed that the shared predisposition to creativity and BD spectrum has a character of inverted U, where a moderate intensity of the features promotes creativity while an acute episode of the illness results in its impairment. Increased creativity in the relatives of subjects with BD was found in the persons not having the symptoms of the illness. However, there are many instances of great artists having entire clinical expression of BD. Whereas the cases of eminent creators with full-blown schizophrenia are rare: most often such persons had their highest achievements before the full development of the illness (e.g., John Nash). In our study, diminished creativity in patients with a clinical diagnosis of schizophrenia was found [66]. In the case of creators suffering from BD, their optimal functioning can be associated with a correct treatment. The treatment with mood-stabilizing drugs such as lithium, carbamazepine, and valproates (but not lamotrigine) can result in a subjective experience of diminished creativity by some subjects [74]. However, in my opinion, the long-term administration of these drugs, causing effective prevention of recurrences, especially in bipolar I subjects, enables them to lead a relatively normal life which may make for a stable creative activity.

In the end, the relationship between creativity and intelligence could be mentioned. It seems that high intelligence is not a *conditio sine qua non* of great creativity, however, it can make an advantageous factor. An example can be the studies of Shelley Carlson, who observed that high IQ was a supporting factor for transforming the attenuated latent inhibition into creative achievements [10]. Similarly, the *NRG1* gene polymorphism was associated with creativity mainly in highly intelligent persons [32]. A recent meta-analysis confirmed a positive although small correlation between intelligence and creative achievements (the mean correlation coefficient from 30 studies was 0.16) [75]. Somewhat higher values were obtained for the correlation coefficient between

intelligence and divergent thinking [76]. Further research on creativity is undoubtedly needed – both about this and other aspects. The phenomenon of creativity still appears as an attractive subject of study.

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