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THE MECHANISM OF NEUROPLASTICITY AND ITS SIGNIFICANCE FOR PSYCHOTHERAPY AND THE EVALUATION OF THERAPEUTIC EFFECTIVENESS

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Summary

The paper introduces the mechanism of neuroplasticity, specifically the ability of the brain to develop new neurons (neurogenesis) and new connections between nerve cells (synaptogenesis) and to develop glial cells. The author presents the evidence proving the existence of neuroplasticity by giving examples of people with serious brain damage who function normally and, above all, of people living with almost no brain or with one hemisphere, or with post-stroke defects. However, the main purpose of this paper is to present the current state of knowledge of the importance of the brain plasticity for the course of psychotherapy, as well as for assessing its effectiveness. The author gives many examples which seem to lend credence to the proposition that recognized psychotherapies (mainly psychodynamic, interpersonal, and cognitive-behavioral ones) actually beneficially alter the brain in patients suffering from obsessive-compulsive disorder, schizophrenia, depression, or panic disorder. These changes most frequently occur in the amygdala and the caudate nucleus (responsible for emotions and learning), the hippocampus (responsible for memory and spatial orientation) and the prefrontal cortex (responsible for planning and behavior modification). The final part of the paper comprises the content concerning the pharmacological support of the cognitive behavioural therapy aimed at „plasticizing" memory taking „erasing" traumatic memories into consideration.

Up to quite recently, neuroplasticity was a totally unknown phenomenon – and surely alien to psychotherapy. Now we know that the brain is quite a plastic organ – it is adaptable and susceptible to change. This discovery has been without a doubt the greatest discovery related to the brain in the last two centuries, which raised us – as Norman Doidge [1, p.18] put it – above the "dark ages of neuroplasticity." It positively revolutionized the traditional knowledge we had about the brain, abolishing the old belief that brain structures cannot be modified. The discovery of the phenomenon of neuroplasticity is absolutely vital to the theory and practice of psychotherapy – above all else it can largely facilitate the assessment of its actual effectiveness.

The discovery of neuroplasticity

In the year 2000 Eric Kandel [2] was awarded the Nobel Prize for demonstrating the synaptic plasticity (synaptogenesis) in the large *Aplysia* sea slug – that is the forming and strengthening of synapses between nerve cells, as an effect of being exposed to stimulation. At the same time it proved Hebb's postulate (the term introduced in 1949 by the Canadian psychologist bearing that name) [3]. To put it simply, it states that simultaneously stimulated neutrons form neutral networks with each other. The harder they are stimulated, the stronger those connections are.

Yet much earlier, that is in the late fifties/early sixties of the twentieth century, Mark Rosenzweig [4] discovered neuroplasticity in rats. He proved, that when placed in a container with ladders, toys, tunnels and treadmills – or, as he called it "an enriched environment" – rats perform noticeably better in a labyrinth test than those which have been put in sterile containers, or a "poor" environment. Thanks to autopsy, he learned that the rats who were kept in a richer environment had considerably larger brains.

An exceptional and exciting feature of Rosenzweig's experiments was that exposing rodents to diversified stimuli gave very diversified results. For instance, when the rats were blindfolded and placed in an environment full of tactile stimuli, there were changes in the areas of their brain responsible for touch.

Stimulating the brain led to physical and chemical changes of this organ, which explains the improvement of cognitive functions, especially learning. When the stimulation was modified and subsequently focused on different parts of the brain, the changes appeared in the specific area of the brain. This discovery has, without a doubt, a great significance also when it comes to therapeutic practice.

The physical environment of the therapy

Thanks to neuroplasticity we may, therefore, create an appropriate "physical therapeutic environment" and thus achieve better and more oriented "therapeutic effects." This is why having a suitably arranged and equipped room for conducting therapy is so crucial. It should be equipped with comfortable chairs or sofas, both for the therapist and the patients; one should never, however, place a barricading piece of furniture (like a desk) between them, though a coffee table is fine. The office should be well ventilated or even air conditioned, have proper room temperature and good lighting – neither too bright, nor too dim. If treating children, it is best to do so in a space full of toys, having also crayons, paints, and other age-appropriate drawing materials on hand [5].

Optimism-pessimism

According to Elaine Fox [6], neutral networks, which are the basis for both optimism and pessimism, are very plastic and susceptible to change. In this context, she describes a "sunny" (i.e. optimistic) and "rainy" (i.e. pessimistic) brain. Nowadays, we know that even small behavioural changes to either avoid what is upsetting or to achieve what is pleasant, after some time become second nature. Those differences result in consistent ways of reacting to the world. However, if the neutral networks controlling anxiety reactions get stronger and start to prevail, the mind may develop an inordinately pessimistic outlook. This, in extreme cases, might lead to anxiety disorders and depression. This is what Fox means by the term

"rainy brain." The optimal mental health is a result of strong and thick networks of the so called "sunny" brain, which might lead to a true blossoming of self and psychological well-being. Those inclinations are deeply rooted and extremely difficult to change – although it is not entirely impossible. Moreover, we already know that we are able to turn this scale – defeat the pessimism and develop a more optimistic way of thinking.

This is backed up by data, especially from the therapy of patients suffering from depression and anxiety disorders – disorders characterised by a pessimistic perceiving of both the past, and the future. It was noticed, for example, that antidepressants are effective precicely because they affect the persistent negative cognitive disorders, that play such a significant role when it comes to depression. Those afflicted with depression remember negative events much better than the positive ones, and antidepressants can weaken those deformities. Therapies– for example cognitive-behavioural therapy – or techniques such as meditation based on mindfulness are also effective in changing harmful changes characteristic of anxiety disorders and depression. This change of "toxic" tendencies of the mind leads to a visible improvement of mental help [6].

Brain damage

A great example of neuroplasticity, of how the human brain can adapt itself to the most extreme conditions, is the case of the patient called by French scientists from the University in Marseille, for the sake of keeping his anonymity, Monsieur Mathieu. Because of a persistent pain in the lower extremities, he was sent to a neurological consult. After he underwent a Magnetic Resonance Imagining examination, it turned out that this public servant, who was leading a completely normal life, had almost no brain. Lionel Feuillet, who studied this extraordinary case, said that inside of the patient's skull there was mostly a chamber filled with cerebrospinal fluid, surrounded by a thin nervous tissue, of the estimated size of almost one-quarter of the regular size of an adult human brain. In spite of such a significant deficiency, the patient did not experiance any problems with memory and other cognitive functions, nor with any affective functions (like experiencing emotions and feelings), senses, or maintaining balance. Although his IQ equalled just 75 (with the average of 100), he definitely could not be qualified as mentally impaired [7].

Other research proving the existence of the neuroplasticity phenomenon and the resulting extraordinary adaptive capacities of the brain was conducted by Velia Gardin of University College London, who studied the method of information processing by the nervous cells of people with hearing impediments. She played films to people with severe auditory impairments, who either could lip-read or used sign language, at the same time monitoring their brain functions. She noticed that although the subjects learned the plot of the movies by looking, it was the area of the auditory cortex responsible for processing not visual, but auditory messages that was involved in the process of understanding the speech. Gardin explains this using the phenomenon of neuroplasticity, thanks to which the brain – in spite of the loss of hearing – learns to associate and connect visual stimuli with aural stimuli, and thus it is able to maintain a consistent capacity to process linguistic information.

Yet the most persuasive and at the same time astounding examples of the extraordinary plasticity of the human brain are people who are able to continue to function normally following a surgical removal of one of the cerebral hemispheres, that is after a

hemispherectomy. This rare surgical procedure is used as a last resort for patients suffering from an acute, drug-resistant form of epilepsy. It is performed in the cases when the epileptic foci are located in one of the hemispheres or in a part thereof. A significant case is that of the nine year old Cameron Mott, who at age three was diagnosed with an especially severe form of epilepsy. Six years after the girl's first seizures, doctors from the John Hopkins University Hospital decided to perform a hemispherectomy. The girl was able to leave the hospital on her own two feet after less than a month after the operation. Moreover, she decided to become a professional ballerina [7].

Researchers claim that the young age of the patients is actually one of the crucial factors contributing to the success of such procedures and the subsequent adaptation of the brain in such drastic situations, as a child's brain is characterised by much higher neuroplasticity than the brain of an adult. This extraordinary speed of adaptation of a child's brain results mainly from its ability to undergo rapid synaptogenesis, that is creating connections between the neurons, as they are responsible for forming the structures that are able to take over the functions from the defected or removed parts of the brain [8].

This does not mean, however, that such possibilities are unavailable for adults. Most recent discoveries in the field of neuroscience contradict previous beliefs that the adult brain is unable to create new neutral networks, and therefore to eliminate its defects. Further proof of the opposite is, among others, the phenomenon of neuroplasticity observed among patients who had experienced a stroke – the sudden artery embolism in the skull, leading to ischemia of a part of a brain, resulting in the cell death of certain neurons, and sometimes even stopping the functions of larger parts of the brain. Yet after some time, usually after about six months, we notice that the defective functions, like hemi-dyskinesia (inability to move either half of the body) or the inability to speak, subside – the brain marvellously regains its functions, returns to its previous state, or simply heals [9].

The increasing state of knowledge about the mechanisms of neuroplasticity is undoubtedly useful when it comes to developing new therapies for people with various kinds of brain damage. In the case of stroke patients we can now plan, in great detail, a course of rehabilitation, taking into account which part of the brain is defective due to the lack of blood flow, and to match appropriate exercises to facilitate the quickest possible creation of new synapses.

Scott Frey of the University of Missouri points out that there is a significant need for change in the method of rehabilitation and training of patients who experienced hemiplegia in the aftermath of stroke. He focuses on the mechanisms of neuroplasticity in patients after amputations and his research using functional magnetic resonance imagining (fMRI) has shown that following an operation of amputating the dominant extreme, for example the right hand, the brain almost immediately learns to use the left hand, by using two hemispheres at once instead of just one. Frey maintains that this might suggest a decidedly higher possibility of achieving full functions of the non-dominant hand. Thus – according to Frey – it would be better to exercise not the dominating part of the body (i.e. the defected one), but the weaker, non-dominant part [7].

Psychotherapy and neuroplasticity

The topic of neuroplasticity is generating more and more emotions also in the domain of psychotherapy, where good news is not a frequent occurrence… Among clinicians, there is an ever-growing interest with this phenomenon and the research on its effects on psychotherapy and the use of neuroplasticity to assess its actual effects. A significant example of such research was conduted by Jefferey Schwartz, a professor at the UCLA School of Medicine in California, who uses the term "self-directed neuroplasticity" in the therapy of obsessive compulsive disorder (OCD) [10]. A classic example of OCD is a someone who persistently keeps thinking about bacteria and constantly washes their hands to keep them away. Schwartz maintains that thanks to the phenomenon neuroplasticity, we can create new connections between neutrons in our patients' brains. His patients learned – on themselves – that the brain is able to change its structure so that the signals or impulses are identified as one of the kind. Proof of physiological changes appearing alongside mental changes was seen thanks to brain scans, which the patients had access to. This resulted in a particular sort of feedback; changes in the way of thinking or the assessments of the situation responsible for obsessions and compulsions lead to changes in specific parts of the brain, while the same imagining and scans shown to patients encouraged them to further work on themselves. Thus, the systematic emotional relearning proved to be a healing factor in their process. This is also a perfect example of how certain experiences can result in higher neuroplasticity, and – to put it more precisely – how they influence the change of emotional matrixes and the forming of the patient's brain.

Even more persuasive arguments demonstrating the extent and strength of experience on neuroplasticity have been made by other studies exploring the same disorder, previously known as obsessive-compulsive neurosis. The subjects were patients with an extraordinarily high compulsion to wash their hands, even a few hundred times each day. The study used positron emission tomography (PET) to establish that in the case of OCD patients, the stimulation of the frontal lobes is consistently higher than the norm [11].

Half of the patients underwent the classic pharmacology therapy using fluoxetine (better known under its trade name Prozac), the other half was treated using behavioural psychotherapy. In the course of psychotherapy, the patients were systematically placed in situations triggering their compulsions or persistent thoughts (i.e. obsessions), while impeding their performance of their compulsion – for example patients suffering from a persistent compulsion to wash their hands were placed near a sink, yet forbidden to use it. At the same time they were trained how to resist their anxiety-inducing thoughts and those pushing them into certain actions (compulsions), like the persistent thought that if they do not wash their hands, they will get an untreatable, or even deadly illness. The compulsions gradually subsided, and after a couple of months of those therapy sessions the patients got totally rid of them, just like after pharmacological treatment.

That kind of behavioural therapy has been successfully used for decades, yet it was only the observations and analysis of the PET scans that let us see what exactly happen, how the positive healing process looks like. A surprising discovery was made: the study shows that after undergoing this therapy, patients experience, just like those successfully treated with fluoxetine, a visible increased activity in the caudate nucleus – the important part of the brain responsible for emotions. This leads us to the conclusion that the experiences of the therapy

altered the way the brain worked – and eliminated the importunate symptoms – to the same satisfying effect as pharmaceutics [12].

Alan Brunet, professor at the Psychiatry Department at McGill University in Montreal, used the phenomenon of neuroplasticity in the therapy of patients dealing with post-traumatic stress disorder (commonly known as PTSD). They were victims of childhood molesting, car accidents, kidnapping or rape, and these deeply traumatic experiences still affected their minds and led to many disagreeable ailments and suffering. Brunet shows a certain success rate of using both pharmacology and the phenomenon of neuroplasticity in therapy. First, the patients were given medicine that helped them supress the emotions resulting from traumatic experiences. Afterwards, they were asked to repeatedly reconstruct the remembered events. Regardless of gender, the patients underwent a "rewiring" of the brain, they broke the current between traumatic memories and their system of identifying danger. This process helped each patient to put the memories (reminiscences) of the trauma in new "brain catalogues," this time not in the virtual present, but in their proper place – the true past.

This is the general rule of neuroplasticity of the brain: neurons, grouping into independent focal centres, create at the same time independent networks. This new way of treating obsessive-compulsive disorder successfully uses the fact that when the patient remembers the traumatic experience, the areas of the brain responsible for memory become more plastic and the healing process takes place in an environment of higher neuroplasticity [13].

Clinicians from California carried out cognitive trainings on order to help patients suffering from schizophrenia, who face various cognitive problems accompanying their general mental state. Sophia Vinogradov and Michael Marzenich used especially developed computer programs to help the cognitive functions of patients who have trouble with perceiving, cognitive processes, and remembering information. Through neuroimaging, they noticed that cognitive exercises altered the areas of the prefrontal coitex – mostly those responsible for focusing attention and problem solving – of schizophrenic patients, bringing them closer to the image of healthy brains. Moreover, in schizophrenic patients, they observed a much lower amount of the BDNF (brain-derived neurotrophic factor) protein – a neutrophine that plays a crucial role in the organization of neutral networks and the plasticity of thy synaptic network, also called the "breeding-ground of the brain." The vitality of BDNF neurons depends on what neurophysiologists call "a specific supportive stimulation", that is the brain's capacity to change due to specific and long-term stimulations. Cognitive training that can retrieve the proper level of BDNF is yet another proof that we have the possibility to achieve neurological changes in the brain [14].

Changes in the brain

As the possibility of tracking neuron function became available, there have been some presuppositions and speculation claiming that we might finally assess whether psychotherapy can really alter the brain. Indeed, research has been made, aiming to explain what happens within the brain in the process of psychotherapy.

D.Y. Liggan and J. Kay [15] attempted to describe various forms of therapy in the context of their potential influence on brain balance (homeostasis) through activating specific brain structures. They came to the conclusion that in the instance of behavioural therapy,

which focusses on basic methods of learning and memorizing – based on classic conditioning and operant conditioning – the changes can be seen in the basal ganglia, hippocampus, and the amygdala. In cognitive therapy, when it is used in order to modify an improper and irrational way of processing information based on deforming cognitive structures, its impact can be noticed by the rise of the activity of the primal prefrontal cortex, and secondarily in the subcortical structures. Psychodynamic psychotherapy, which concentrates primarily on interpersonal relations, quite visibly activates the many neural networks in the cortical-subcortical area, which significantly includes the lateralization of psychical functions in both hemispheres of the brain.

The currently available research on the changes in the brain following psychotherapy of patients suffering from depression, borderline personality disorders, and anxiety disorders, show that cognitive-behavioural therapy (CBT), dialectical behavioural therapy (DBT), interpersonal therapy and psychodynamic psychotherapy alter the brain functions of major depressive patients (MDD, according to the DSM-V classification), patients with obsessive-compulsive disorder (OCD), panic disorder, specific phobias, social phobias, post-traumatic stress disorder, and borderline personality disorder [16, 17]. This does not mean, however, that other types of therapy do not influence changes of brain structures and functions – all we can say is that the data collected in studies into the impact of other therapies is still too small to prove those connections.

Psychotherapy and pharmacological treatment

Most comparative studies show that psychotherapy and pharmacological treatment lead to similar changes. There are, however, some empirical data which would point to certain differences in the regularity of the effects of those diverse ways of treatment. Some of the most crucial are those made by K. Goldapple and his team [18], who compared the changes in patients suffering from severe depression after cognitive-behavioural therapy (CBT) and after monotherapy using paroxetine. Similarly, a study done by H. Karlsson et al. [19] noticed a visible difference between the results of a short-term psychodynamic therapy and pharmacological treatment using fluoxetine in the same group of patients.

In a different study, patients with severe depression were randomly divided into two groups – one underwent a short-term psychodynamic therapy, the other was put on fluoxetine treatment [30]. Research shows that psychotherapy contributed to an increase of serotonin receptor (5-HT1A) density, the lowering of which is a pathophysiological symptom of severe depression, while pharmacological treatment did not provoke such positive changes. At the same time, the fluoxetine improved the effects of dopaminergic neurotransmitters on the side of the thalamus. The thalamus is the largest part of the diencephalon, serving as a kind of "transmitter station." It receives sensory stimuli – with the exception of smell – and transmits them to the cerebral cortex. From this research we can conclude that the healing process of patients suffering from severe depression (MDD) progresses differently if the patient undergoes psychotherapy or pharmacological treatment. Some studies suggest that the risk of the reoccurrence of depression is lower for patients who underwent psychotherapy than for those treated only with pharmaceutics [20, 21].

Interesting results were shown by a study using EEG and neuroimaging, comparing changes in the brain after psychotherapy and pharmacological treatment of patients diagnosed

with depression. M.E. Thase and his team [22] observed that the changes of sleep patterns which were the effects of successful cognitive-behavioural psychotherapy are similar to those using antidepressant medication. S.D. Martin and his team of researchers [23] used the SPECT method (single-photon emission computed tomography) compared the changes in the brain of two groups of patients: the first one had gone through venlafaxine treatment, the other underwent interpersonal psychotherapy (IPP). This mode of psychotherapy concentrates on the recreation of the interpersonal connections with the closest environment (family, colleagues at work) which had been destroyed or frayed due to the depression, and at the same time attempts to deal with the symptoms of this illness. In both groups the therapy resulted in an activation of right basal ganglia. Furthermore, in patients taking venlafaxine there was a visible activation of the back area of the right temporal lobe, and in patients undergoing interpersonal psychotherapy – in the limbic part of the cingulate cortex. A. L. Brody et al [24] conducted a study using PET neuroimaging on patients with diagnosed depression, who were either on paroxetine or were undergoing interpersonal psychotherapy [IPP]. Preceding the start of both therapies, the patients experienced increased metabolism in the prefrontal cortex, the caudate nucleus and the thalamus, and a decrease of metabolism in the temporal lobe. Although the effectiveness of pharmacological treatment was noted significantly higher than of interpersonal therapy, both methods of treatment resulted in the normalization of metabolism in the beforementioned brain structures. The only difference is that the paroxetine treatment led to normalization of the prefrontal cortex on both sides, while in IPP patients the effects were visible only in the right side.

Cognitive-behavioural therapy and the brain

The most proof that the mechanism of neuroplasticity can be triggered by therapy concerns cognitive-behavioural strategies (CBT) or behavioural therapy.

As a result of CBT, the changes noticed were both in the areas of the brain responsible for emotions, and in those responsible for logical thinking. Inappropriate nervous connections in the limbic system, and to put it more precisely, in the amygdala and the hippocampus, are the main factors in experiencing of various phobias. The former structure, responsible for processing of emotionally-charged information – above all stemming from stress and anxiety – plays an important role, as it warns about incoming danger. The latter plays a crucial function in the process of memorising (declarative memory), including traumatic memories. It is also responsible for spatial imagination. Those are the two symmetrical structures within the limbic system that are “repaired” by the cognitive-behavioural therapy [25].

Research of the French scientists using neuroimaging techniques show, that CBT is also beneficial for the prefrontal cortex, which lies in the front part of the frontal lobe. It is responsible for the working memory, the planning of movement and action, considering their aftermath, and for the evaluation of the situational context – thus it slows down spontaneous and often violent emotional states. People with injuries or deformities in this area of the brain cannot evaluate if a certain behaviour is appropriate and tolerated in a given situation or not. Moreover, the defects of the prefrontal cortex might result in a higher nervousness and stronger impulsiveness [26].

The study made by Baxter [11], conducted with the help of positron emission tomography (PET) shows that patients suffering from obsessive-compulsive disorder (OCD)

who take part in cognitive-behavioural therapy (CBT) and are on imipramine, manifest a decrease of the hyperactivity in the caudate nucleus. This data is corroborated by other studies that used brain imaging techniques. Subsequent studies using PET, this time on depressive patients, show a decrease of activity in the prefrontal lobe due to interpersonal therapy and antidepressants. There was also a stabilized metabolism in the frontal area of the brain after CBT in patients with a diagnosed social phobia. The results of those studies prove the hypothesis that various kinds of mental disorders lead to more or less typical malevolent changes of the brain's activity, which may improve as a result of psychotherapy. Research on those topics shows that psychotherapy is based on cortical top-down mechanisms, while pharmacological therapy is passed on the basis of subcortical bottom-up mechanisms. This is consistent with the view that the brain is a neuroplastic organ. This dichotomic view is corroborated by research showing the placebo effect in the cerebral areas, as contrasted with the subcortical and limbic areas and the brain stem, in the use of fluoxetine in treating severe depression. This leads us to a conclusion that in brain activity, there is no separation, but an interactive change of psychological processes into biological processes and *vice versa*.

M.K. Shear and his team [27] came to the conclusion, that when dealing with patients diagnosed with panic disorder, the use of cognitive therapy increases the chances of them being able to resist a panic attack following a pre-therapy lactate infusion. R. Joffe and his team [28] determined the density of thyroid hormones in patients diagnosed with depression who underwent cognitive therapy. They concluded that following a successful therapy, there was a decrease of thyroxine levels, while the patients who proved resistant to therapy – the levels of this hormone were above average.

The plasticity of memory

Although neurobiologists have been studying the brain using various methods of imaging for only a relatively short time, there are already some ideas leading to describing how "bad" memories are mad. When someone has an unpleasant or even a traumatic experience, the region of the brain called the thalamus transmits sensory information to the amygdala, which subsequently categorizes this unpleasant memory as emotionally charged and important and keeps in the long-term memory in order to avoid similar danger in the future. Neural networks placed in the hippocampus start to develop a "map" of a memory as soon as only a few hours after the experience in question. The synapses (connections between neutrons) linked to the experience become stronger, due to the so called "long-term potentiation," which leads to the "saving" of events in the form of memories. Steve Ramirez, a neuroscientist from the Massachusetts Institute of Technology, claims that when a human being memorizes something, various regions of their brain "converse with each other," in order to preserve all aspects of this experience – images, sounds, tastes, smells and kinaesthetic experiences – in as much detail as possible. However, through the process of "re-remembering" they are susceptible to many modifications. Although one is usually certain that their memory is a direct recreation of their past experiences, the truth is, that their memories undergo constant changes and modifications as a result of the stream of new information. This process is called the "reconsolidation" of memory. Moreover, some data points to a "mobility" of memories stored in the brain. They proof the hypothesis of the

plasticity of memory, and seem to contradict the belief that with time, memories become "crystalized" [29].

A "quietening" or even a total "fading" of a traumatic memory calls for the creation of new, less dangerous or less anxiety-inducing associations, triggered by the same sensory "cues." This means that even in the case of very old memories there is still some possibility to change, that even they exhibit some plastic potential. Psychotherapists use this phenomenon during the so-called "exposition" – a therapeutic procedure in which the patients are confronted with anxiety and fear triggers in a safe environment, which in turn helps them to achieve a sense of control. In order for this process to work, it is crucial that there is a manifold communication between various parts of the brain: the hippocampus transmits the information about the change of the event to the prefrontal cortex, which slows down the work of the neutrons – and the conditioned anxiety reaction – in the amygdala. For some people, however, this process is hindered, and they have more difficulty with dealing with the constantly returning, unwanted memories. Neurobiologists still admit that the reason why people have so diverse reactions to traumatic experiences is still unknown [29]. Gregory J. Quirk, a neuroscientist from the University of Puerto Rico, points out that this might be attributed to the fact that some people have a less developed synaptic network connections with the amygdala in the prefrontal cortex than others, and thus are unable to "calm down" their brain with information such as "calm down, you are not in danger" or "be calm, this is in the past" [30].

Nowadays, researchers more and more frequently attempt to manipulate the process of memory consolidation, that is the "saving" of memories in the human brain. In 2014, scientists of the Center for Neutral Circuit Genetics – an international collaboration of the Japanese RIKEN Institute and Massachusetts Institute of Technology – were successful. The neurobiologists managed to successfully change bad memories into good memories in a male mouse. They did it using optogenetics, a technique of inserting gene sequences coding light-sensitive protein into nerve cells. These proteins travel to the neutron's cell membrane and – because of the light – activate or hinder the activity of the cell. Thanks to this, the scientists were able to assess in which part of the rodent's brain its memories of being shocked with electricity are created. They observed that above all else, this process engages the neutral network connecting the dentate gyrus of the hippocampus with the amygdala. Then, they activated those neutral circuits using lasers. Each time the mouse moved to a particular place in its cage, the scientists created a negative memory – the rodent quite quickly learned to fear this area. Afterwards, the male was allowed to "flirt" with a female, at the same time the scientists stimulated the same neutrons, which "remembered" the negative experience. This way, they managed to change the memory from an unpleasant one to a pleasant one. Since the change, the mouse freely moved all around its cage and the place which he once feared no longer raised any anxiety [31].

There is a constantly increasing number of scientists who claim, that it is possible to improve memory using pharmaceutics. Mark Bouton and his group of scientists of the University of Vermont, have spent almost the last two decades on researching the effects of combining pharmacological treatment using an antibiotic (D-cycloserine) with cognitive-behavioural therapy (CBT). The medicine is used to fade out strong emotional reactions, especially to treat post-traumatic stress disorder (PTSD). It connects with NMDA receptors

(*N*-methyl-D-aspartate receptors), which play a crucial role in the processes of remembering and learning, and may also stimulate the creation of glutamic acid in the amygdala, which leads to the reconsolidation of memories. So far, the best results of cognitive-behavioural therapy augmented by D-cycloserine medication were achieved when the patients were given small doses of the medicine 3-5 hours before the therapeutic session [32].

In the scientific and medical community, however, there is no general accord as to the therapeutic value of the abovementioned antibiotic. The results of one of the recent studies show that PTSD patients who were given D-cycloserine experienced an increase of symptoms [32]. S.G. Hoffman [33] claims, that in order for the medicine to be applied safely, the therapists must be very particular and thorough in prescribing the right dosage and finding the best time of its injection and interaction with the cognitive-behavioural therapy. He also adds that if the therapeutic impact is much weaker than the initial conditioning process which caused the negative memory, the medicine may, paradoxically, strengthen the element triggered by the anxious reaction. Others have observed, however, that the improvement of the patients' condition when the therapy and the S-cycloserine treatment were successful, was much more significant than the improvement of those in the placebo group, yet those, who even after the therapeutic sessions still experienced strong anxiety, did worse than the placebo group [34].

Although the findings of most recent studies – conducted primarily on animals – seem optimistic, there is no doubt that there is still a long way before we are able to "cancel out" human memory or "delete" certain nagging or traumatic memories. Yet even now numerous types of reliable therapy methods can make positive changes to the brain – if neuroscientists will be able to uncover how this happens, perhaps then they will be able to free humans from anxiety disorders.

Conclusions

Roger Wolcott Sperry – an American neurobiologist, who was awarded the 1981 Nobel Prize for his extraordinary achievements in neurobiology – noticed that the human brain is a much more complex entity than all our other systems combined. He wrote: "The degree and kind of inherent individuality each of us carries around in his brain – in its surface features, its internal fiber organization, microstructure, chemistry – would probably make those differences seen in facial features or in finger-tip patterns look crude and pale by comparison" [35, p. 152]. According to this, it is our brain that makes us one-of-a-kind and special.

Without a doubt, neurobiology is the big new hope and promise of psychology, as it offers a glimpse into the individual differences of particular patients, it can uncover diverse ways of thinking, learning, processing information, and emotional reactions – which are conditioned by the functions of regions, which are characteristic and individual to particular human brains. Relying on the knowledge of the brain's natural neuroplasticity, the therapist can use the potential of the phenomenon to create positive changes for the patient.

Yet we must bear in mind that the studies on the neurobiological aspects of psychotherapy are far from perfect – both content-wise and when it comes to methodology. Although there has been a quite significant progress in the technical methods of brain imaging, thanks to which we may now observe the work or activity of particular regions of

the brain and the changes thereof, the method of evaluating the results of these observations is still too superficial and overly simplified. What raises the most doubts is the question of how we should interpret the images registered during the examination of the brain, and also the fact that the main model on which the analyses are based is actually the cognitive model [36]. In spite of those concerns, thanks to the most recent state of our knowledge about the brain, along with the possibility to conduct various neuroimaging and neurofunctional studies and examinations, we can now make more and more reliable findings as to the biological aspect of psychotherapy. This may lead to further research as to the connection between psychotherapy and neuroplasticity, and bring attention to the possibilities of a biologically-focused view on psychotherapy – which, in turn, might lead us to be able to share this knowledge with not only specialists.

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