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CURRENT AND TRADITIONAL VIEWS ON THE BRAIN WORKS

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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SUMMARY

The present paper argues that the development of a new methodology in studying the brain has resulted in a change of our views on the way it works, has seen the emergence of new ideas, and a considerable modification of traditionally accepted theories. The most significant are neuroplasticity, negative activity network (NAT), the nature of aphasic disorders, and the approach to the localization of brain functions. New brain imaging techniques have confirmed also the ability to change the neuronal circuits by mental force. Moreover, new techniques have brought about a rise in new methods for both the diagnosis and rehabilitation of individuals with various brain disorders. Most valuable in this respect has proved to be neurofeedback. We have concentrated on the most important contributions of Prof. Pąchalska in the implementation and development of these new ideas on brain functioning. We also emphasize the fact that her theoretical considerations are firmly based upon her extensive (forty years) work with brain damaged patients.

Key words: ERPs, neuronal circuits, neuromarkers, neuromodulation, neurofeedback

INTRODUCTORY REMARKS

As an example of Prof. Pąchalska's approach we herein present a recent example from a study on a patient with PTSD (see: Fig. 1). His behavioural parameters of cognitive control, such as omission errors were quite normal, but ERP measurements clearly indicated hypo-activation of the pre-supplementary motor cortex – a hallmark of dysfunction of the brain system responsible for action inhibition/overriding of prepared action in situations when this action either is not needed or must be replaced by another action.

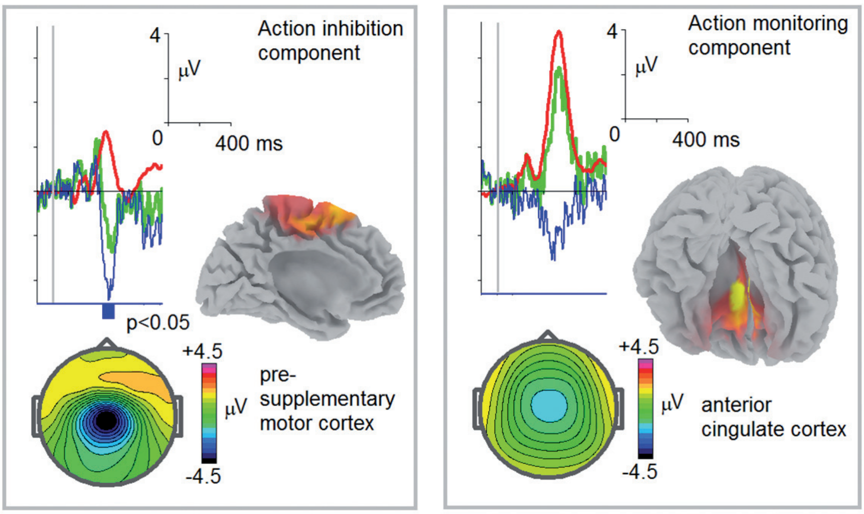

Fig. 1. Dysfunction of the pre-supplementary motor cortex in a patient with PTSD.
Left and right. Two independent components of event-related potentials in the GO/NOGO task for the patient (green) in comparison to the grand-average ERP of a group (N=23) of healthy subjects of corresponding age (red). Bottom – topography of the component. Right – sLORETA image of the topography
Source: Półrola, Kaczmarek, Góral-Półrola et al (2016)

Knowing the brain dysfunction in this patient we can suggest neuromodulation techniques for the activation this cortical area by means of methods: neurofeedback, tDCS or TMS. This example demonstrates the use of the new methodology for the assessment of brain dysfunction as well as for constructing a protocol of neuromodulation.

INTRODUCTION

We have recently witnessed a rapid development of brain imaging techniques, which is accompanied by the emergence of new ideas concerning the brain and its functioning. At the same time, this gives rise to heated disputes on the validity of new theories and the consequent approaches to diagnosis and therapy of brain disorders. Traditionalists are, as a rule, reluctant to accept new views, arguing that they stand in opposition to well established facts. One of reasons for the persistence of scientific paradigms is that the brain is forced to make a selection from the abundance of stimuli that attack our senses every day. The selection enables us to create a coherent and comprehensible image of the world. Otherwise the world seems chaotic, disordered, and terrifying. This fear results from a lack of understanding and hence being unable to predict what might happen in the near and far future. That is why fear and a lack of security are one of the main symptoms of psychotic illness. The world's coherence, both at the individual and social level, is secured by cognitive schemas, to which scientific paradigms equally belong. The social schemas provide for the feeling of security enabling us to anticipate the acts of others and to act in accordance with social rules at the same time. It is worth recalling here that our perception is not the result of a synthesis of formerly analysed features of objects but our perceptions are created in the process of sculpturing, which makes possible the emergence of a given figure out of the overwhelming number of sensations (Brown, 1988, 2015; Kaczmarek, 2012; Pąchalska et al. 2014; Pąchalska et al. 2017).

In the domain of science such stability is ensured by carefully designed research paradigms. According to Kuhn (1996) scientific paradigms do not change for long periods of time, and all problems tend to be solved within the conceptual apparatus delineated by a particular paradigm. Within this period, which Kuhn calls the period of 'normal science,' problems are solved in accordance with the generally accepted rules.

The existing paradigms constrict our ability to perceive and comprehend facts that appear contradictory to established knowledge and beliefs. This may be best observed in the field of medicine. Doctors are trained to delineate specific features of the syndrome consisting of symptoms typical of a given illness. Certainly this helps them to arrive at a proper diagnosis but it may also be the cause of some diagnostic mistakes since symptoms often vary to a considerable degree in individual patients (Brown, 1988. Brown & Pąchalska, 2003). The spectacular development of brain imagining techniques has created a belief that we soon will be able to read the minds of other people. This is a long way off, and does not need to lead to success. Yet, some ideas that seemed impossible to imagine turned out to be true in the course of time.

DEFAULT MODE OF BRAIN FUNCTIONING

The constant activity of the brain (observed also in the state of rest) was described already in 1929 by Hans Berger, the inventor of electroencephalogram. He wrote: "*we have to assume that the central nervous system is always, and not only during wakefulness, in a state of considerable activity"* (Raichle, 2010, p.44). Berger was able to note the ceaseless electrical activity of the brain with the use of his apparatus. This idea was for a long time ignored despite the rapid development of brain imaging techniques such as Positron Emission Tomography (PET) or functional Magnetic Resonance Imaging (fMRI), in which oxygen uptake is used as an indicator of neuronal activity. One reason was that experiments which applied those techniques focused on the activity of the brain, while performing specific tasks. It was assumed that the active areas are switched on only to perform a given act, and they stay inactive before doing so.

The activity of hitherto "silent" neuronal nets (often treated as brain areas) has been possible to reveal due to the measurement of the relationship of oxygen delivery to oxygen utilization, which is referred to as the oxygen extraction fraction (OEF). This is connected with the fact that an increase in blood flow is accompanied by a decrease in oxygen consumption, and, vice versa, the consumption of oxygen increases with the decrease in the blood flow. It was found that the oxygen extraction ratio (OEF) remains spatially uniform, while a healthy person is awake lying quietly in a scanner with his eyes closed. Raichle and collaborators (2001) have proposed to use the OEF as a baseline state activity of the brain. They observed a continuous activity of the brain, when people were sitting quietly in a chair or lying with their eyes closed. The use of the above described technique made possible the observation that the most active were midline areas within the posterior cingulate and precuneus as well as within the medial prefrontal cortex.

As pointed out by Raichle et al. (2001, 2010), the above mentioned areas play a significant role in the continuous gathering of information about the outside world. This may explain why focusing attention on novel stimuli results in a reduction of its activity. They might be also connected with consciousness, which finds its possible confirmation in the fact that in patients waking from a coma a restoration of metabolism can be noted mainly in the parietal lobes, including the precuneus. It might be worthy to note that the precuneus is located at the border of occipital, parietal, and temporal lobes just like the angular gyrus. The angular gyrus occupies the dorsal area, and plays a significant role in cognitive functions. It enables a combining of visual (occipital lobe), somaesthetic (parietal lobe, and auditory (temporal lobe) information, and as stated by a prominent Russian neuropsychologist, Aleksandr R. Luria (1974), associations of associations take place there. Since the precuneus is situated in the medial part of the brain part of the brain, it might play a similar role in the work of the Default Brain Network (DBN), i.e., in the synchronization of the work of various brain systems and in the consolidation of memories (Kropotov 2009). Another name used to define the system in question is the Task-Negative Network since it was found that its activity decreases during performing particular tasks. At the same time, strong connections of structures forming the DMN with the structures of the limbic system along with its rich connections with the prefrontal area indicate that it may be also important for the integration of cognitive and emotional processes (Luria, 1974, 1980; Kaczmarek, 2012). Moreover, some findings indicate that DMN may include also the insula, hippocampus, and septum (Heimer et al. 2006; Raichle, 2010).

Another name used to define DMN - the Task Negative Network (TNN) - is a bit misleading for two reasons. First, the brain shows a considerable activity while we are at rest, and the increase of the consumption of energy reaches only 5% while performing particular tasks. Second, TNN was found to play a considerable role in the cognitive tasks that require planning, problem solving, scene construction, and forming associations. In fact, TNN works in orchestration with the so called Task Positive Network (TPN), which is directly engaged in externally directed tasks such as perception. An important role in the coordination of the work of the TNN and TNP is played by the frontoparietal control system. In other words, all three networks (or systems to be more exact) make balance-keeping possible between internal and external information processing, which is imperative for adapting behaviour to changing environmental conditions (Spreng, 2012). Such a balance seems to be lacking in the case of some mental illnesses such as schizophrenia, in which the TNN appears to be pathologically active. In consequence, schizophrenics are apt to take internal information to be external, and often interpret their thought as voices coming from others (the 'outside').

As already noted, proper functioning of our mind is secured by a delicate balance of the brain networks, which requires a fine coordination of their work. It is highly probable that such an orchestration is provided for by the basic electric activity of the brain (reflected by TNN), which may be evaluated with the use of the modern technique of neurometrics called QEEG (Roy, 1990). Special computer programmes enable quantitative analysis of EEG records, and the delineation of types of brain disorders. It is also possible to discriminate neuromarkers specific for a particular disorder, such as frontal syndrome, schizophrenia, and ADHD. Moreover, they enable delineation of an disorder that is masked by the major one: as was the case in one of the patients treated at the Cracow Rehabilitation Centre in whom a diagnosis of schizophrenia made doctors ignore the symptoms of depression (Pąchalska et al. 2014). In addition, neuromarkers has made possible the planning and applying of an effective therapeutic procedure. The clinical practice of Prof. Pąchalska provides numerous examples of the spectacular efficacy of such an approach. The list of her works describing that approach can be found in the paper of Kropotov (in the present volume).

LANGUAGE AREA?

An ability to communicate with others is very important, and underlies all social interrelations. It seems very simple for those who have acquired a good command of their native language, but this turns out to be a serious problem for those who do not know the main language used in a given society. Such difficulties are encountered by people who either have just arrived in a new country or those who live in minority groups. They often produce grammatically incorrect and often incomprehensible utterances. Consequently, they are frequently considered to be rather dull and not able to undertake any serious job. This is connected with a tendency to evaluate the objects and people we meet in accordance with the previously developed images and stereotypes. A significant part of those images is not only behavior but also language. It is worth pointing out that utterances produced by the above mentioned groups often remind one of the language of brain-damaged subjects suffering from aphasia.

As in the case of other cognitive functions research on linguistic communication disorders gives rise to an abundance of controversial results. A traditional neurological approach relies upon the physiological foundations providing a motor-sensory dichotomy. Taking into account psychological factors results in a number of classifications, of which the best known is the distinction between expressive and receptive aphasia. Other authors propose one take into account the localization of the brain lesion, and, consequently, divide aphasias into anterior and posterior ones (Pąchalska, 1999; Tylor-Sarno, 1981). Yet, careful analysis of aphasic symptoms shows that such dichotomies are major simplifications (Brown & Pąchalska, 2003; Pąchalska et al., 2014).

Moreover, further research has revealed that linguistic communication becomes impaired also as a result of brain injuries outside the traditional speech zone. The most significant role seems to be played by the prefrontal region and the parts anterior to the Broca's area in particular. Patients with damage to that area manifest difficulty in producing longer utterances but they are able to utter separate words, to repeat simple statements, recite poems, and to say automatized phrases. They are, however, at a loss when asked to say something on a specific topic and as a rule they limit themselves to expressing well known stereotyped ('hackneyed') phrases such as „The sea is wide and deep" or „The mountains are very high" (Kaczmarek, 1987, 1993).

It might be worthy to point out that the Broca's and Wernicke's regions have not been considered to be the main language zones by those authors. In fact, Broca used the term „*faculty du language articule*„ to describe a function of the area which then came to be denoted by his name. In this he followed his teacher Bouillaud who spoke about „the faculty to coordinate the individual movements of speech" (Eling 1986: 15). Moreover, beside the motor faculty Broca distinguished a faculty of understanding utterances, a general faculty of language as well as separate faculties for other forms of communication such as writing or signalling. Thus, Broca never claimed language to be limited to a restricted region of the brain as it was later assumed. Recent MRI studies also point to the fact that Broca's area is to be considered as one of the modules of a complex system of language processing (Bookheimer, 2005).

Highly relevant in this respect are the observations made by Kimura (1976) drawn from her studies on the relationship between manual skills and speaking. She found that individual and paired finger flexions, which require precise control of individual movements, were more easily performed by the left hand of right-handers. She further wrote that „the peculiar contribution of the left hemisphere to manual skills did not consist in increased discreteness of movement, but perhaps in the increased efficiency with individual movements could be coordinated or organized into a sequence" (Kimura 1976: 147). From the above it follows that a sequential organization of constituent units of an action is the main function of the left hemisphere taken as a whole. Naturally, the posterior parts of the „speech region" are involved in the control of verbal production as well as in the paradigmatic organization of linguistic information. Thence, disruptions to the phonemic hearing and word retrieval difficulty are most typical of lesions in that part of the cerebral cortex.

There have been a number of reports relating to the linguistic abilities of the right hemisphere. In most cases, however, they are limited to naming objects (see Gazzaniga and Hillygard, 1971; Code, 1987; Bradshaw, 1989). As far as comprehension is concerned the right hemisphere appears to be capable of understanding concrete nouns, single phrases as well as semantic relations between the most frequent words. Yet, an ability to differentiate various grammatical forms reflecting tense, number or the passive voice is a task that proves to be too difficult for right-brain-damaged patients (Moscowitch, 1976; Code, 1987). It was also observed that damage to the right hemisphere results in an inability to understand humour and metaphoric language (Gardner, Brownell, Wapner, Michelow 1983; Code, 1987).

Another important lesson that we can learn from an analysis of aphasic disorders is that language usage depends on the emotional state of the speaker. This had been already stated already in late 1800 by a prominent English neurologist, Hughlings Jackson (1958). He observed that severe aphasic patients, who were not able to produce even a word on request, uttered quite elaborate curses. That was further confirmed by a number of studies (Luria, 1970; Tylor-Sarno, 1981). Following Jackson some authors believe that this is due to the abilities of the right hemisphere (Gainotti, 1972; 2003; Bradshaw, 1989). It is, however, quite plausible that the limbic system comes to play a significant role here, as the damaged left hemisphere does not control it any more (Kaczmarek, 1984, 1988, 1998). Prof. Pąchalska rightly points out that the above observation are best explained by Microgenetic Theory (Pąchalska et. al., 2018a. 2018b).

FILTERS IN THE MIND

Emotional states work also as a filter having a strong impact upon the interpretation of what we hear and what we say. Hence, a person who is under strong emotional stress is often not able to comprehend what is said to her/him. All of us have also experienced difficulties in expressing ourselves under strong emotions, and a very strong emotional arousal may even leave us speechless. Hence, all of us, when very tired or excited, may resemble an aphasic patient. As mentioned above, it is often the case with minority groups that feel excluded and disliked.

The situation becomes further complicated due to other filters that operate in our mind. One of them is connected with a phonemic hearing, the other with processing the received data within the brain. The phonemic hearing enables us to distinguish speech sounds that occur in our mother tongue, but at the same time makes it difficult to discriminate the speech sounds of another language. It means that we not only have to learn how to distinguish new sounds but we must overcome our old habits in listening and speaking. That is why children are much better at learning languages; their phonemic hearing is not yet developed so they are able to hear the speech sounds as they really sound. It is also worth pointing out that phonological awareness has a strong impact upon the ability to read and write in a target language (Kaczmarek, 2003).

Yet another filter is connected with cognitive processes. We are apt to pay attention to those objects and events that are of interest to us, and to neglect those that we consider insignificant. From out of those observations, as well as the opinions and relations of others, we create our own image of the world. In consequence, the images of the world for each individual person differ to a considerable degree. This may lead to many misunderstandings, stereotypes, and prejudice, which influence our attitudes towards others. This concerns not only the attitudes towards minorities but also the attitude of minorities to the mainstream culture of a given country. Thus, a child who overhears that people from the outside world are bad and untrustworthy will be reluctant to talk to a teacher who is a member of that alien and dangerous world. This should be taken into consideration by those who opt to let immigrants stay in their own culture. Quite often it leads to the creation of ghettos out of which it is very difficult to extract oneself due to a lack of language knowledge and acquaintance with the social rules of the country they happen to live in.

Here one needs to recall that Prof. Pąchalska argues that brain-damaged patient also feel excluded from society, and therefore, she has included the socialization of such patients as a significant part of their therapeutic program (Pąchalska, 1999; Pąchalska et al. 2018a).

BRAIN PLASTICITY

Nowadays, the idea of neuroplasticity is generally accepted. Indeed, it is at the heart of all therapeutic procedures. Spectacular manifestations of brain plasticity can be observed in patients who were given art therapy program headed by prof. Pąchalska at the Cracow Rehabilitation Center. Of special interest might be the case of Maria L., in whom the brain stroke resulted in severe motor aphasia and a right-sided paresis. In addition, symptoms of amusia were observed as she was not able to sing even a simple tune, despite the fact that she had been a piano teacher at a music school before the stroke. During the course of her art therapy, she discovered the ability to paint, and her paintings proved to be really good. Moreover, she has not only recovered her abilities to play the piano but she has taken up her former job as a music teacher. It should be stressed that Maria L. was over sixty at the moment of the stroke so her case proves the existence of plasticity eqaully in an elderly brain (Pąchalska et al. 1998, 2014).

Another significant example is a patient diagnosed with schizophrenic, who was also given art therapy after being run over by a car, something which caused a severe brain contusion. He has become a prominent artist, exhibits his paintings all over the world, and his works are well received by art critics (see Pąchalska et al., 2013, 2014). It also needs to be pointed out here that after applying new neurometrical techniques discovered were neuromarkers of depression. In consequence, the treatment of the patient was changed, which resulted in his complete recovery (Pąchalska et al. 2018a).

Schwartz and Begley (2003) argue that patients suffering from obsessive-compulsive disorder (OCD) may also benefit from brain plasticity. They report that the cognitive-behavior therapy they applied resulted in the alternation of the metabolism of the brain circuit affected in that disorder. Positron Emission Tomography (PET) revealed a decrease in the abnormally high hyperactivity of brain structures within that circuit (mainly the caudate, the orbital frontal cortex, and the cingulate gyrus).

The components of the above mentioned circle play different but complementary roles in controlling emotions. Their most important role, however, is to integrate emotions and reasoning. Schwartz and Begley (2003) argue that the most significant in this respect are the tonically active neurons (TANs) located in the caudate. They were found to fire in reaction to either negative or positive stimuli. It is of interest to note that TANs take part in reacting to reward-related signals. At first it was suggested that they might contribute to detecting cues for a potential reward (Graybiel et al, 1994) but later studies suggest that they might rather signal the reward prediction error. Whereas Shimo and Hirosaka (2011) are of the opinion that TANs play a significant role in the detection of the context discrimination by modulating the activity of projection neurons.

Yet, it should be remembered that not only the above mentioned neurons but the whole striatum is a significant component of the reward detection loop, which, in addition, includes nucleus accumbens, the anterior cingulate cortex, and the medial frontal cortex to mention only the basic structures (Kropotov, 2009). Moreover, the role of these structures is not limited to controlling emotions. They also take an active part in a context-depending learning by the reorganization of previously learned behavioral patterns (Amemori et al., 2011). Besides, they are components of the attention system (Kropotov, 2009; Pąchalska et al., 2014).

CONCLUSIONS

The above review shows that Prof. Pąchalska takes an active part in what Kuhn (1996) called a scientific revolution. This refers to the period when the accumulation of new facts and discoveries makes most scholars realize that existing paradigms are no longer able to explain those phenomena. In fact, the acceptance of new ideas requires not only the understanding on the part of other scholars but of an attentive, general audience. As pointed out by Haslam et al. (2014), this may be noticed both in the field of science and the arts. One does not have to look far, Vincent van Gogh gained recognition only after his death, thanks to the Postimpressionists who started to paint in a similar style.

In neuroscience, a new approach to understanding the brain function that was neglected for quite a long time has been Microgenetic Theory. This was formulated as long ago as in 1988 by Jason Brown but only recently has it gained the

Fig 2. After the inauguration of the Academic Year 2017/2018 in Andrzej Frycz Modrzewski Cracow University (Prof. Maria Pachalska, third from the left, with the Rectors of the University and the "Bractwo Kurkowe").
Source: archives of the Polish Neuropsychological Society.

attention and recognition of neuroscientists. Here it needs to be stressed that a great part in the popularizing, developing new creative parts, and proving of this theory was played by Prof. Pąchalska. Indeed, she did not only made it widely known but she had considerably contributed to its development. Above all she has demonstrated that an unfolding of cognitive processes depends not only upon the self but also upon the whole organism as well as the social environment including culture broadly understood (see: Fig. 2. Pąchalska et. al., 2018a).

Her other important contribution is a new understanding of the idea of the localization of functions. She stresses that even the use of the term "neuronal nets" does not reflect the real interrelations between the brain and psychological functions. Above all, this does not show their dynamic changeable nature. Therefore, she advocates the use of the term "neuronal patterns."

The most valuable facet of her theoretical considerations is that they are based on extensive clinical experience. No wonder it has enabled her to revise a number of invalid assumptions as exemplified in the present paper, albeit only in part. It might be also worthy to remind the reader that Prof. Pąchalska is one of founders of the highly respected international journal *Aphasiology.*

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