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Brain Plasticity and the Idea of the Functional System

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Нейропластичность и идея функциональной системы

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Abstract. The paper shows that the idea of brain plasticity underpins Luria's theory of the functional system and his approach to diagnosis and rehabilitation of brain-damaged patients. Although the functional system is frequently quoted in neuropsychological literature its important facets are as a rule overlooked or misunderstood. First of all, the functional system is not only composed of various often quite distant brain structures but it undergoes changes in accord with the arriving circumstances including chances and difficulties encountered by a given person. Accordingly, these alternations may be positive or may be enforced by brain diseases, which results in performing a particular function in different ways.

The notion of neuroplasticity was also incorporated in the works of Luria on development and culture. It should be noted that he stressed the role of social factors in the evolvement of cognitive processes with special emphasis put on social means of which he considered language to play the most important role. Luria argued that the use of these tools results in alternations in the structure and flow of mental functions both in children and in adults. It was exemplified in his experiments with twins and with inhabitants of remote villages in Central Asia. All his ideas have found confirmation in contemporary studies. First, all

mental processes depend upon the interconnections between neural clusters of changing patterns depending upon the nature of the task performed and the life experience of an individual. Second, the brain works depend to a considerable degree upon the organism as a whole a well as a social environment, which many authors link with the emergence and functioning of the mind. Third, the approach to diagnosis and remediation techniques that takes into account the feelings and life story of the patient is nowadays accepted not only in dealing with brain-damaged patients but also in the case of other disorders. Also, those traditionally labeled as somatic. In addition, we observe the revival of case studies in the scientific literature.

Keywords: *dynamic functional systems; brain plasticity; mind; development; environment; culture*

Аннотация. В статье показано, что идея пластичности мозга лежит в основе теории А. Р. Лурия о функциональной системе и его подхода к диагностике и реабилитации пациентов с повреждениями головного мозга. Хотя термин «функциональная система» часто используется в нейропсихологической литературе, но важные аспекты его трактовки, как правило, упускаются из виду или неправильно понимаются. Функциональная система состоит из различных, часто достаточно удаленных друг от друга структур мозга, но она может и претерпевать изменения в связи с возникающими обстоятельствами, включая трудности, с которыми сталкивается тот или иной человек. Эти изменения могут носить не только положительный характер, но и быть вызваны заболеваниями мозга, что приводит к выполнению той или иной функции различными способами.

Понятие нейропластичности также встречается в трудах Лурия, посвященных развитию когнитивных процессов. Следует отметить, что он подчеркивал роль социальных факторов в развитии когнитивных процессов, особо выделяя социальные средства, он считал, что наиболее важную роль играет язык. Лурия утверждал, что использование этих средств приводит к чередованию структуры и потока психических функций как у детей, так и у взрослых. Примером тому служат его эксперименты с близнецами и с жителями отдаленных сел Центральной Азии. Все его идеи нашли подтверждение в современных исследованиях. Во-первых, его утверждение о том, что все психические процессы зависят от взаимосвязей между нейронными кластерами изменяющихся паттернов, с учетом характера выполняемой задачи и жизненного опыта индивида. Во-вторых, его идея о том, что работа мозга в значительной степени зависит от организма в целом, а также от социальной среды, которую многие авторы связывают с появлением и функционированием разума. В-третьих, его подход к методам диагностики и коррекции, учитывающий чувства и жизненный опыт пациента, сегодня применяют не только при работе с пациентами, получившими повреждения головного мозга, но и у больных с другими расстройствами, включая те, которые традиционно обозначаются как соматические. Сегодня в научной литературе вновь возрождается интерес к анализу отдельных случаев подобных заболеваний.

Ключевые слова: *динамические функциональные системы; пластичность мозга; психика; развитие; окружающая среда; культура*

Dynamic Nature of Luria's Functional System

It often presumed that neuroplasticity is a newly discovered revolutionary phenomenon, while in fact it was reported already in the 1780s by the Italian anatomist Michele Vincenzo Malacarne. He trained one of the two birds from the same clutch of eggs and one dog from the same litter for several years. Afterward, he compared the brains of the trained and untrained animals and found that the cerebellum of the trained ones was significantly larger (Costandi, 2016). At the beginning of the 20th century an eminent psychologist and behaviorist, Karl Lashley (1923) was giving different motor tasks to a rhesus monkey and derived different motor maps in the motor area of its brain. The idea of the immutability of the central nervous system prevailed, however, to the end of the twentieth century when it was dispelled by the experiments of Merzenich and colleagues (Allard, Clark, Jenkins, & Merzenich, 1991; Merzenich et al., 1983, 1984).

It might be, therefore, worthy to remind that the idea of brain plasticity lays at the basis of both Luria's theory and his approach to clinical work. And it was formulated already in the first half of the 20th century. It is best expressed in his concept of a functional system. However, the review of neuropsychological literature shows that despite being generally known its important facets are often missing. First, its dynamic malleable character is quite frequently overlooked. Second, but equally important, are close links with social and cultural factors, and third, perhaps most significant is the tenet of Luria's approach to diagnosis and rehabilitation of brain-damaged patients. He expressed it clearly in his autobiographic book *The Making of Mind: A Personal Account of Soviet Psychology*:

> Truly scientific observation is not merely a pure description of separate facts. Its main goal is to view an event from as many perspectives as possible. The eye of science does not probe 'a thing' an event isolated from other events or things. Its real object is to see and understand the way a thing or event relates to other things or events […] it seeks out the most important traits or primary basic factors that have immediate consequences and then seeks the secondary or 'systemic' consequences of these basic underlying factors. *Only after these basic factors and their consequences have been identified can the entire picture become clear.* The object of observation is thus to ascertain a network of important relations. (Luria, 1979, p. 177–178)

This quotation reveals the essentials of syndrome analysis, which aims to delineate the basic defect linked to the damage of a specific brain area. Careful observation of the ways the patient is performing particular tasks and difficulties that might appear makes it possible to unveil a cluster of interrelating symptoms that constitute a syndrome characteristic of a dysfunction of the brain area in question.

It is also worth noting that a similar type of structured observation was also used by another great psychologist, Jean Piaget who christened it a clinical review. Fundamentals of that approach were summarized by Édouard Claparéde who wrote:

> This clinical method, therefore, which is also an art, the art of questioning, does not confine itself to superficial observations, but aims at capturing what is hidden behind the immediate appearance of things. It analyses down to its ultimate constituents the least little remark made by the young subjects. It does not give up the struggle when the child gives incomprehensible or contradictory answers, but only follows closer in chase of the ever-receding thought, drives it from cover, pursues and tracks it down till it can seize it, dissect it, and lay bare the secret of its composition. (Claparéde, 1926, p. xiv)

We have decided to give this rather lengthy quotation since it pertains to Luria's manner of examination. For him, syndrome analysis meant not only the evaluation of errors made by the patient, while performing particular tasks, but also the observations of the patient's strategies to overcome difficulties that appeared. It is a well known clinical fact that these difficulties often stem from compensatory mechanisms, which in effect distort a clinical picture of the illness. Hence, Luria's approach was focused on the patient, and the type and amount of help the patient needed to complete the task.

Claparède referred also to another significant aspect of a clinical method centered on the process. Namely, a requirement to elaborate the material gathered since such an approach leads to the abundance of available data. In the case of Piaget, it was his biological background that enabled him precise organizing and classifying different types of conversation. Luria was able to do it due to his medical qualifications. In fact, he applied rules and structure of medical history and incorporated psychological tasks making it possible to get a clear picture of neuropsychological symptoms.

Anyone, who had a chance to observe Aleksandr Romanovich performing a neuropsychological assessment, was deeply impressed by his art and craftsmanship. Especially, by his ability to come into close contact with the patient and to put questions that enabled revealing the true nature of symptoms observed. He also used to say that classical neurological examination is veterinary in its nature since neurologists seem to forget that we can learn a lot about a patient's difficulties while talking with him or her (personal communication).

Another significant tenet of the Lurian method arouse from his close contacts with two great Russian physiologists: Nikolai Bernstein and Pyotr K. Anokhin. Bernstein posited that all activities are complex and goal-oriented and require the interaction of multiple components controlled by the central organ. Due to the complexity of behaviors the control must be secured by a pattern of interacting factors of a functional system. At the same time, Bernstein (1961, 1967) emphasized the dynamic character of such systems in response to interactions of the organism with its surroundings. The idea of dynamic functional systems providing for adaptive behavior and supporting homeostasis in response to both internal and external changes that might occur was also proposed by Anokhin (1935, 1940, 1964). Also, Anokhin argued that functional systems are self-organizing nonlinear systems composed of many synchronized widely spread components. For our present considerations of particular importance is Anokhin's discrimination between simple and complex functions. An example of a simple function

is a production of bile by the liver while complex functions are in fact composite multiple processes of which mental functions are most typical exemplars.

Anokhin argued that all complex functions are composed of multiple elements and, thence, they cannot be localized in a specific brain area, therefore, their "localization" has to be distributed in its various parts. This assumption gave rise to the creation of the Lurian complex dynamic system composited of three basic blocks or subsystems. His theory of three functional systems is generally known so we shall not discuss it in detail. Of significance, however, is the above mentioned dynamic malleable character. It means that the structure of the Lurian functional system undergoes continuous alternations in accordance with changes taking place in the environment as well as in the organism itself during its maturation and development. This property of the system discussed is closely linked to the ideas formulated by Lev Vygotsky (Luria & Vygotsky, 1992; Vygotsky & Luria, 1930). Notably, Aleksandr Romanovich used to emphasize his intellectual debt to Vygotsky who was not only his collaborator but also a close friend. They both believed that observation of the manner of unfolding or disruptions of psychological processes provides an insight into their true nature revealing their real complex character.

The premise of the participation of each area of the brain in numerous functions is also frequently quoted as a basic feature of Luria's theory. Recent studies, however, assert that the dynamic systemic location of particular functions in the brain is organized into working assemblies of neurons that integrate individual neuronal nets. Such a "wiring diagram" has been called a connectome to emphasize the significance of connections between neural cells within particular neural nets and within the brain as a whole. Seung (2012) posits that four factors play a significant role in these processes: reweighting, reconnection, rewiring, and regeneration (defined as four R's): reweighting means strengthening or weakening connections among neurons; reconnection connotes creating and eliminating synapses; rewiring is attained by growing and retracting branches, and regeneration occurs as a result of creating new neurons and extinction of the existing ones.

It might, therefore, seem that Luria's model is a bit out-fashioned due to the level of knowledge about the brain work of that time. We can, however, find a statement referring to the "clusters of brain neurons" that get integrated into different functional systems in his book *Human Brain and Mental Processes* (1963a), at least in the original Russian edition. Moreover, Luria often stressed that the three functional units distinguished by him are created of smaller functional units and that the combination of all these units makes possible efficient functioning of the whole brain. He also argued that higher mental functions are the output of interacting and intervariable brain systems. It again is in accordance with the findings that different patterns of neural networks enable smooth flow of different processes (see Costandi, 2016; Doidge, 2007; Kaczmarek & Markiewicz, 2018; LeDoux, 2002).

The idea of systems consisting of interchangeable connections of different brain structures acting in accord with the particular action is closely connected with Luria's approach to neuropsychological assessment and the idea of a symptom. He stressed that particular symptoms may differ to a considerable degree when one or another link is bro-

ken since it results in the disruption of the whole functional system or its subsystems to be exact. It is another significant aspect of Luria's theory. The other is the idea that the work of the functional system is secured by the participation of all levels of the brain (Luria, 1963a, 1963b, 1973a, 1980).

We have focused on the above-described aspect of neuroplasticity since it is closely linked to Luria's theory and his clinical work. That is also the reason for presenting works of classic authors since their ideas lay at the basis of Luria's functional system. Other manifestations of neuroplasticity such as neurogenesis and glial plasticity are discussed in another paper (see Kaczmarek, 2020).

The Social Brain

The above-described studies show that tightly interconnected networks, which are responsible for performing particular functions, undergo continuous alternations. They encompass not only changes in neural connections but also the functioning of neural clusters (nets). These processes are affected to a considerable degree by our environment and all events that we experience during our life. It was neatly summarized by Marcus (2004) who stated that our brain is not wired but prewired. Indeed, it is not only prewired but also soft-wired since it undergoes continuous changes during our life-span (see Merzenich, 2013) The "wiring" depends to a considerable degree upon social and cultural factors, hence, the term the social brain has been coined (see Dunbar, 1998, 2016; Gazzaniga, 1985, 2012; Glozman & Krukov, 2013; Goleman, 2006; Graziano, 1967).

The impact of the environment upon the brain works is emphasized by many authors (e. g. Bao & Pöppel, 2012; Costandi, 2016; Dehaene, 2014; Johnson, 2017; Varela, Thompson, & Rosch, 2016). It is yet another feature of Luria's writing that found its confirmation along with the advancement of diagnostic techniques in neuroscience. As mentioned earlier, Luria and Vygotsky believed the human brain to develop and undergo changes as a result of social and cultural influences. These changes occur in two ways: (1) those related to alternations in the content and structure of cognitive processes Luria considered as mental plasticity, (2) the changes in brain structure mostly identified with neuroplasticity (see Mikadze, 2014). The role of environmental factors in these processes illustrate the following extract:

> In order to explain the highly complex forms of human consciousness, one must go beyond the human organism. One must seek the origins of conscious activity and 'categorical' behavior not in the recesses of the human brain or in the depths of the spirit, but in the external conditions of life. Above all, this means that one must seek these origins in the external processes of social life, in the social and historical forms of human existence (Luria, 1981, p. 25).

The impact of culture upon thinking was confirmed in field experiments performed by Vygotsky and Luria (Luria, 1971, 1979). The study found that illiterate inhabitants

of remote villages in Uzbekistan refused to solve syllogisms and other abstract problems and their reasoning was mainly based on their everyday experience. They were ready to discuss only the syllogisms drawn from their practical experience and describing familiar situations. When asked to classify the object presented to them, they took into account the relations between those objects occurring in real-life situations and not logical categories. Luria points out that those of them who undertook school education were able to accomplish such tasks. Similar results gave studies performed on Polish manual workers who also relayed on their personal experience when solving logical tasks (Tłokiński, 1995). For example, they explained the meaning of the proverb: *Make haste slowly* in the following way. "Well, that depends. It is good for work safety, but bad for work efficiency for productivity" (Tłokiński, 1995, p. 141; see also Kaczmarek, 1999).

Luria's findings were also confirmed by a group of psychologists in experiments performed in far-off places of the Kamchatka peninsula. In addition, one of the experimenters, Janna Glozman, noted a very important fact: "This tendency for situation-based generalization was more pronounced in nomadic herdsmen than in village inhabitants with the same level of education. So, the practical life conditions are more important for reasoning functioning than the level of education" (Glozman, 2018, p. 12).

The second expedition and its findings are quite well known but Luria (1931) also led a large group of psychologists during the first expedition to Uzbekistan. During that expedition, he concentrated on visual perception and "visual thinking" of nomads. He found that their processing of visual and spatial tasks differed from the abilities of educated persons. It showed that the influence of culture concerned also non-linguistics functions. As mentioned earlier the impact of social and cultural factors is nowadays emphasized by many authors, which allows the conclusion that one more of Luria's ideas has found confirmation with the development of neuroscientific studies.

Brain and Environmental Factors

This brings us to Luria's interest in socio-cultural and developmental psychology. He discussed the importance of social means, with special emphasis put on language, in both developing and shaping cognitive functions in many of his works (1928, 1971, 1976, 1981). First of all, Luria and Vygotsky (1992) believed the human brain to develop and to undergo changes as a result of social and cultural influences. Luria stressed that the social activity of a child has a considerable impact on the manner his/her cognitive processes are organized (Luria, 1961, 1976, 1981). He stressed the importance of a child's adaptation to the requirements of his surroundings pointing to its impact upon the maturation of the brain and asserted that this adaptation depends upon social environment and conditions to a greater degree than natural inborn processes linked to maturation. As mentioned earlier, he emphasized the role of tools the child has a chance to use and believed that language is the most significant "tool" enabling cognitive development, which is linked not only with functional but also structural neuroplasticity (Luria, 1961). A marked influence

of the children's environment on their cognitive development was presented in the book *Speech and the Development of Mental Processes in the Child* (Luria, & Yudovich, 1959). Two boy twins at the age of five, retarded in their cognitive development, were separated. The main reason for the separation was that they were using specific jargon to communicate and used mainly gestures to communicate with adults. The boys were enrolled to separate kindergarten groups. It resulted in the spectacular development of their speech abilities during the period of ten-month. Moreover, one of the boys was given special language training. As a consequence, his mental abilities were more developed than those of the untrained brother. For example, he was able to classify objects presented to him in accordance with the logical classes, while his brother organized the objects based on their irrelevant features. Accordingly, he put the red streetcar together with a carrot since they both were red. Moreover, the trained boy became an organizer of the activities that required planning, while before the training he was a subordinate to his physically stronger and less retarded brother. Similar results reported Douglas and Button (1978) who provided specific language training for two twin girls. Tskhovrebova (2018) reported that Luria and colleagues were conducting broader studies on monozygotic and dizygotic twins. They found that younger monozygotic twins (aged 5 to 7) were more similar between themselves in cognitive capacities than dizygotic twins, however, these differences were much smaller in older (aged 11 to13) twins (see also Bowden, 1971). It indicates the significance of the environment. In her paper Tskhovrebova (2018) also argues that Luria proposed "various modifications of twin method for psychogenetics" (p. 893).

Awareness of the impact of environmental factors upon genes has led to the creation of the new branch of science — epigenetics. Studies show that severe stress has a significant impact on the development and ability to cope with stressful situations of the off-springs of the individuals exposed to such traumas (see Carey, 2012; Francis, 2011). Also, it was observed that stress and depression lead to the hippocampus shrinkage due to the adverse reaction of its cells (Dokter & von Bohlen und Halbach, 2012; Duman, 2004; Duman, Malberg, & Nakagawa 2001; LeDoux, 2002; Sapolsky, 2004). Nowadays the new medications for depression treatment were created. These drugs stimulate genes to create new proteins that induce alternations in the level of neurotransmitters (Duric & Duman, 2013; Gerhard, Wohleb, & Duman, 2016; Medrihan et al., 2017).

At the same time, studies show that structural changes may relate to the development of new brain cells. Accordingly, the proliferation of new hippocampal neurons and an increase of the hippocampus volume in London taxi drivers were observed. Woollett and Maguire (2011) linked it with the necessity to memorize a complex map of the city addresses and routes. On the other hand, Maguire, Woollett, and Spiers (2006) reported no such changes in bus drivers probably because they drive a constrained set of routes. It allows the conclusion that neuroplasticity is linked both with alternations within neuronal circuits, neurogenesis, and epigenetic changes caused by environmental factors, which again is in line with Luria's approach to the brain works.

It might be also worth recalling studies that revealed the possibility of reconstructing neuronal circuits with the use of mental exercise. Pascual-Leone and colleagues (1995)

trained two groups of people in the skills of playing the piano. The first group was playing a five-finger piano exercise for two hours for five days while the participants of the other group were asked to imagine they played it during the same period. As a result, both the improvement of playing skills and changes in the cortical representation of the hand used in the exercise were observed in both groups.

Also, neuroimaging studies using positron emission tomography (PET) and functional magnetic resonance (fMRI) brought examples of structural alternations in brain networks induced by mental meditations (Brefczynski-Lewis, Lutz, Schaefer, Levinson, & Davidson, 2007; Davidson & Lutz, 2008; Lazar et. al., 2005; Lutz, Brefczynski-Lewis, Johnstone, & Davidson, 2008; Lutz, Greischar, Perlman, & Davidson, 2009; Slagter, Davidson, & Lutz, 2011; Telles, Singh, & Balkrishna, 2015). A meta-analysis on 21 brain imaging studies examining 300 meditation practitioners showed that:

> …eight brain regions consistently altered in meditators, including areas key to meta-awareness (frontopolar cortex/BA 10), exteroceptive and interoceptive body awareness (sensory cortices and insula), memory consolidation and reconsolidation (hippocampus), self and emotion regulation (anterior and midcingulate; orbitofrontal cortex), and intra- and interhemispheric communication (superior longitudinal fasciculus; corpus callosum). (Fox et al., 2014, p. 48)

Furthermore, Schwartz and Begley (2003) reported changes in the brains of patients with obsessive-compulsive disorder (OCD) after applying effective cognitive-behavior therapy. The changes were observed mainly in the orbital frontal cortex, the cingulate gyrus, and the caudate and manifested in a decrease of hyperactivity of these brain structures. These are structures closely linked to feelings, and needs, which are the main drives of all human beings. Not to look far, recent findings reveal that the human brain is directed toward historically beneficial goals, which is strictly connected with the sensation of pleasure. It may be best observed in various kinds of activities leading to addiction, which, at least at its first stage, are strongly connected with the activation of the brain reward circle (Volkow & Fowler, 2000). It was also observed that our brain shows greater plasticity to memorize the desired (rewarded) states (Kropotov, 2009).

Clinical Benefits of Brain Plasticity

The studies of Schwarz and Begley showed the significance of brain plasticity for the rehabilitation of individuals suffering from mental disorders, and thus are linked to a clinical tenet of Luria's work. As mentioned earlier, the very idea of the functional system assumed the possibility of its alternations in the case of brain damage. These alternations might occur spontaneously or require hard work of both the patient and his/her therapists depending upon nature and extend of the lesion. Thus, the idea of plasticity lies at the heart of Luria's approach to therapy of brain-damaged patients. Neuroplasticity also benefited patients who took part in a therapy program at the Cracow Rehabilitation Center un-

der the guidance of prof. Maria Pąchalska (Pąchalska, Kaczmarek, & Kropotov, 2014; Pąchalska, MacQueen, & Knapik, 1998). Spectacular improvement could be observed in Maria L., who suffered from severe motor aphasia and right-sided paresis as well as amusia after the brain stroke. It was very painful for her since she was a piano teacher before brain injury. At first, she was reluctant to take part in art therapy but after several sessions, she discovered that her painting skills were surprisingly good. An example of her painting abilities is presented in *Figure*. It is a copy of a picture produced by a prominent Polish artist, Stanisław Wyspiański, drawn after one year of rehabilitation. It had encouraged her to redouble her efforts to improve her piano skills. After several years of training, she was able to resume her work as a music teacher, which shows that brain plasticity is possible also in people over 60 years of age.

Figure. Helenka with a vase by Stanisław Wyspiański (right); a copy made by a patient of M. L. aged 60, after one year of rehabilitation (left).
Source: Clinical material of Maria Pąchalska (with permission)

Maria L. later produced many other works of art, both watercolors and oil paintings, but she kept them as a memento. We have decided to present this patient not only because of her newly acquired painting skills but also because she regained the ability to sing and to compose melodies as well as the improvisation capability. It should be emphasized that art therapy is only one of the components of the carefully planned remediation program, and many more patients have improved their motor and cognitive abilities in the course of this therapeutic procedure. Most spectacular is the case of patient W.W. who has become a renowned artist whose paintings are exhibited all over the world (see Kaczmarek, 2020; Pąchalska et al., 2013, 2014).

Conclusions

The above-described facets of Luria's works show that his ideas have found confirmation in the studies that benefited from the refinement of neuroimaging techniques. At the same time, we have tried to draw attention to these tenets of Aleksandr Romanovich that used to be overlooked or misunderstood. First of all, it concerns the notion of the functional

system and its complex, dynamic, and malleable character. Moreover, Luria (1973b) believed it to be a "*self-regulating system*" thereby ensuring the appropriate flow of mental activities. Siegel (2016) argues that:

> …self-organization is not dependent upon a programmer or a program. In other words, it is not caused by a specific something; it simply emerges. Self-organization is an emergent property of complex systems that simply arises as a function of complexity. As a self-organizing process, it is recursively shaping that from which it arises. (p. 49)

The idea of emergence is nowadays frequently raised in writings discussing the connection between the brain, mind, and consciousness (see Chalmers, 2010; Damasio, 2018; Dehaene, 2014; Graziano, 1967; Johnson, 2017; Koch, 2012).

The above remarks show that Luria's understanding of the functional system was very broad and multifaceted. Another manifestation of the complexity of his approach is neuroplasticity, which he did not limit to the reconstruction of the functional system as a result of brain disorders. He stressed its complex and adaptive nature closely linked with the individual life experiences and events that took place in the environment. As described earlier, this idea is now generally excepted and finds its reflection in the frequently used terms social brain or social mind (e. g. Boyer, 2018; Gazzaniga, 2012; Graziano, 1967; Kaczmarek, 2012; Steven & Fernbach, 2017; Tomasello, 2014). Awareness of the significance of social factors in the way the brain works is also reflected in launching an international journal *Social Neuroscience*.

It is really impressive that these ideas were expressed by Luria already in his first book (Luria, 1922/2003). Glozman (2020) quotes the following credo formulated by Luria in this work:

> — To deal with the concrete personality, the living human being, as a biological, social and psychological unity.
> — To study individual regularities, uniquely determined sequences, that is to combine a description of individual, unique processes with the study of lawful, regular processes.
> — To study an individual human mind as a whole and the particular mental phenomena as functions, elements of this whole, developing in this concrete human personality, with the possibility of change through the transformation of social conditions.
> — To study individual values of the examined psychological phenomena for the life of the actual personality. (p. 43)

Two additional aspects are highlighted here. Namely, the significance of taking into account the personality of an individual in neuroscientific studies. It is closely linked to contemporary studies on neuropsychological foundations of the self and identity (Feinberg & Keenan, 2005; Pąchalska, Kaczmarek, & Bednarek, 2020; Pąchalska, Kaczmarek, & Kropotov, 2020; Zaytseva et al., 2014). Another significant tenet is the notion of the wholeness of the mind. This idea has been developed by David Bohm (2002),

physicist and philosopher, who drew from the quantum theory to explain the principles of the work of the brain and mind. He stressed their close interrelationships, holistic nature, and the flux of action. Similar ideas were voiced by a number of prominent philosophers, and their ideas were summarized in the book under a telling title *Emergence: Contemporary Readings in Philosophy and Science* edited by Bedau and Humphreys (2008).

In sum, the above-presented data show that the scope of Luria's interests goes beyond clinical matters limited to diagnosis and remediation of brain disorders but encompasses basic problems of human existence. Naturally, captured from a psychological point of view. Moreover, his ideas are developed by researchers representing various branches of science also when they do not refer to his writings.

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