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How Culture Shapes Mind, Neurobiology and Behaviour

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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Review Article

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ABSTRACT

This article has the intention to explain how culture influences human mind and brain by referring to recent research in relevant disciplines: i.e., cultural psychology, cross-cultural psychology, genetics and epigenetics, neurobiology and neuropsychology, and cultural neuroscience. Cultural-historical psychology, represented by Lev Vygotsky and the concepts 'lower' and 'higher' psychological functions are used as theoretical tools to explain how culture generates human mind and brain. Lower psychological functions are the natural, non-volatile, instinctive functions not involving language, signs or thought. In the brain this mind state is represented by neural networks established before birth primarily by the genetic outfit. The higher psychological functions are created after birth by the individual in cultural/social interaction and communication. These functions are unique to every individual, depending alike on genetic features, lower psychological functions and socio-cultural experience, and represented by neurons all over the brain connected with synapses created after birth.

Keywords: Culture; neuroscience; mind; epigenetic; brain; Vygotsky.

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1. INTRODUCTION

Cultural impact on psychological functions, mind and consciousness has been studied for some decades in cultural-, and cross-cultural psychology. Cross-cultural psychology has demonstrated empirically the discrepancy in human psychological functions in different cultures. Cultural psychology has dealt with the same topic also theoretically, trying to answer the question: how can culture be transformed to psychology? Research in recent years has demonstrated the importance of culture and the cultural experience also for the function and the structure of the brain. This understanding is not brand new; Lev Vygotsky discussed the relationship or inter-functionality between culture, biology and mind nearly one hundred years ago. As trained neuropsychologists and cultural psychologists he and Alexander Luria became the forerunners of today's empirical evidence concerning how brain due to its ability to change and develop are shaped by motoric and mental activity in a specific culture. Between 1930 and 1990 there was little interest in culture in psychology and neuroscience. However in the last two decades psychologists and neuroscientists have again focused on culture as a relevant topic [1,2,3,4,5] (see below). Less than twenty years ago, neuroscientists began to study cultural phenomena represented in the brain by using functional MRI. Today *cultural neuroscience* (CN) is flourishing.

Culture has recently also been discussed as a factor influencing basic and biological human features: the genes due to epigenesis and the brain due to brain plasticity. Culture is therefore taken into consideration in traditionally biological disciplines in contemporary research. The multi-directional interactions between biology, mind and culture has become a popular topic in human sciences.

At the end of the 20th century disciplines dealing with human beings, psychology included, had a strong emphasizes on biology, brain and the genes. The 1990s was the "decade of the brain" and the Human Genome Project (HGP) took place from 1990 to 2003. It is some kind of a paradox that studies of the human biology, especially the genes and the brain, led to the recognition that genes function and brain structure are dependent on culture. Today it is accepted also in mainstream psychology that development of human psychology cannot be understood without taking culture into consideration. Culture is, after all, stored in people's brain [6]. The human brain is uniquely evolved to acquire cultural capacities, such as language [7] and morality [8]. The interaction between biology and culture is a significant topic in contemporary psychology.

The aim of this article is to present empirical data from cultural psychology, cross-cultural psychology and cultural neuroscience that illustrate how culture affects mind, genes and the brain. The paper also presents a theoretical approach to the topic, combining recent knowledge about brain development and Vygotsky's cultural-historical psychology. The purpose is to explain how culture is transformed into higher psychological functions and develops mind and brain.

All animals are influenced by their cultural environment. Human beings, however, has something in addition to (other) animals that make cultural impact particularly important. Human beings have *higher psychological functions* [9], the ability to use language and combine it with thinking. The acquisition of language as a psychological tool is of special significance for human beings and for their higher functions. Other living organisms are not affected by language and cultural signs to the same degree. To describe and explain how semiotic systems influence brain and mind is therefore an important task when studying human development. Vygotsky and Luria have delivered important contributions to language acquisition, and also dealt with the theoretical and epistemological branch of the problem, something which is quite uncommon in the empirical oriented cultural neuroscience. Their conceptualisation and theories are used in this paper to explain how culture is internalized and fastened in the brain. Most of the contemporary research in cultural psychology, cross cultural psychology, and cultural neuroscience gives empirical data for the relationship between biology, psychology and culture. These disciplines do not to the same degree give an explanation or a theoretical model for how culture with language are internalized and become a significant feature of man.

Cultural neuroscience (CN) represents a novel empirical approach to demonstrating bidirectional interactions between culture and biology. It focuses explicitly on ways that mental and neural events vary as a function of cultural traits (e.g. values, practices and beliefs) [1]. Cultural

psychology and neuroscience might seem to inhabit opposite ends of the scientific spectrum. The emerging field of CN, however, has sought to combine the theories and methods of these two disciplines [10,2] and has become a research field motivated by the intriguing question of human nature: how do cultural traits interact with the genes, neurobiology and shape psychological functions and behavior? CN has the potential of contributing a new view of person as biologically prepared and, yet, fully completed only through cultural participation [3].

Traditionally the brain has been looked upon as hardware, with a fixed structure and capacity. Until late in the 20th century most psychologists was not aware of the brains plasticity and the synaptogenesis. In the last 20 years the conceptualization of the brain as a biological structure changing and developing has contributed to a totally new comprehension of human psychological development. The same happened with the new understanding of the influence of the genes on psychology and behavior. It came as a surprise that the function of genes depends on environment and therefore on culture. Both cognitive and biological psychology had for a long time excluded culture as significant for human psychology. Today this has changed. Human psychology cannot be understood if cultural influence on mind, genes and brain is omitted. In recent years cultural psychology has studied the impact on psychological phenomena (i.e., perception, cognition, emotion, self-concept, motivation) of a varied characteristics or constructs of culture (i.e., individualism-collectivism, holistic-analytic). A significant problem for an understanding of human psychology is to clarify the mind/brain relationship. Due to the complexity of the phenomenon and the possibility of choosing different perspectives makes it understandable that there are disagreement and multiple explanations of the same phenomenon [11].

Human beings develop ontogenetically from a biological organism to cultural individuals. Our genes and inborn qualities and instincts enable an adaptive and developing human brain—a cerebral structure that receives cultural impact and develop and increases its capacity due to its ability to change both structure and function. Qualities are transformed, reshaped and new patterns or configurations in the mind and brain are created all the time. Old functions or elements are still part of a human being, but they have changed to another form, with another meaning and signification during the ontogenetic development. New concepts and activity develop mind and consciousness and this psychological activity also changes the brain by establishing new connections between neurons [11]. The brain adapts to the elaboration of the mind and changes its structure and function to represent the altering and developing mind. When the brain establish new connections between neurons and make a denser network of brain cells, this changing of the brain's structure and function also makes it easier to create and acquire new cultural facilities in the next round. The area of the higher psychological functions in brain and mind will develop and increase at the expense of the lower, elementary, instinctive, non-volatile functions established at an earlier stage of brain development.

The 'machine paradigm' which has been a dominating approach to the human brain cannot explain this transformation and has therefore been under attack in recent decades. The comprehension of the human as a machine and the brain as a computer excludes the possibility for humans to take part in its own development, and it therefore cast out of science any self-determination approach [11].

To summarize: this article has three main aims: (1) To provide theoretical ideas and insights that are useful in illuminating the inter-functionality between culture, mind and brain and the extent to which a person's brain function is determined by genetic background (nature) or/and by culture and experience (nurture). (2) To explain the sociocultural emergence of the psychology of individual human beings, especially the transformation of participation in sociocultural activity into psychological phenomena. (3) To explain how the cultural mind and consciousness is fastened in the brain structure and how the growth (synaptogenesis) of the brain improves the acquisition of other psychological tools and increases the domain of the higher psychological (mind) functions, superseding the lower instinctive functions.

2. CULTURE AND CULTURE IN PSYCHOLOGY

Everybody is born into specific, but dynamic culture that *cultivates* (the Latin word for culture) every human being. Culture is a term that has been given many meanings. More than 50 years ago Alfred Kloeber and Clyde Kluckhon presented in their article *Culture: A Critical*

Review of Concepts and Definitions 164 definitions [12]. In psychology culture is most commonly applied as the term for the patterns of knowledge, beliefs and behaviour, or the set of shared attitudes, norms, values, goals and practices that characterize a group. Children acquire cultural norms and values in the same way as they acquire language, through interaction with older members of their cultural group.

Mainstream psychology and neurosciences have picked up on culture as a significant topic only in the last decades [1,2,3]. The exception is the cultural-historical psychology in Soviet in the 1920s and 30s [13,14,9,15] and some neuropsychologists in the 1980s and 90s [16,17]. The cultural-historical tradition represented by Vygotsky and Luria is however not often mentioned by contemporary cultural psychologists and it does not seem to exist in the present cultural neuroscience. An aim with this article is therefore to underline the relevance of this approach for contemporary cultural neuroscience; especially for theoretical discussions and explanation of empirical results.

According to Geertz ‘‘there is no such thing as a human nature independent of culture . . . We are . . . incomplete or unfinished animals who complete or finish ourselves through culture’’ [18, p. 49]. ‘‘Biological beings become human beings through their engagement with the meanings and practices of their social world’’ [19, p. 32].

2.1 Importance of Language

Language exists independent of the individuals in a culture. Due to the “invention” of (written) language no species can accumulate progress across generations as smartly as humans. We can pass our experiences and transmit information and innovations across time and place to the future generations in a unique way. Acquired characteristics are in this way inherited, not genetically but culturally.

Evolutionary biologists have for many years discussed the reason why *Homo sapiens* became a new species so different from its animal ancestors. Most often they have looked for anatomical or morphological characteristics, for instance the size of the brain, the functional benefits due to bipedalism, i.e. the ability to move on two legs, or the hand with opposable thumb able to seize [20]. The unique ability to use language and symbolic systems were hardly mentioned by biologists. Focusing intently on biological changes they do not refer to cultures as a cause of selection. Evolutionary biologists did not analyze the relationship between biological and cultural development [21].

With *Homo sapiens* and its substantial growth in brain size more than 200,000 years ago, an accelerated change began and humans developed spoken language, rituals, arts and ability to think. From a biological and anatomical point of view however, we are in principal similar to our ancestors 200,000 years ago. But in a cultural and psychological sense there are such big differences from our ancestors that it cannot be explained by biological adaption [21]. To explain radical changes in humans the importance of language and other psychological tools have been accepted as a major contribution to human development. The Neanderthals, in many ways similar to *Homo sapiens* from a biological point of view, did not develop in the same way. They missed the voice-tube and could not develop a differentiated spoken language. Even if the voice-tube had some biological drawbacks, for instance increased exposure to choking and less effective chewing [22], it represented an enormous enhancement in flexibility concerning production of sounds, improvement in communication and in this way represented the start of human beings with higher psychological functions as we know them today [21].

3. CULTURAL AND CROSS-CULTURAL PSYCHOLOGY

Two decades ago, cultural psychology was re-born by some landmark books [23,24,25,26]. To the extent that sociocultural practices diverge, so will psychological functions [24]. Since the 1990s the burgeoning field of cultural psychology has demonstrated the subtle differences in the way individuals’ process information, think about themselves and others, release emotions, etc., differences that appear to be a product of cultural experiences leading to culturally acquired psychological abilities. Contemporary cultural psychology focuses primarily on how culture creates mind or psychology (especially higher psychological functions), not the brain or the genes. Richard Shweder brought together several strands of thought related to the interface of culture and the mind and memorably observed that “culture and the psyche make each other up” [25]. Around the same time, the field also witnessed some highly influential reviews of

empirical evidence for cultural influences on human psychology [26,27]. These reviews demonstrated substantial cross-cultural variation in psychological processes, thereby showcasing the possibility that many psychological functions might be linked systematically, and much more closely than had ever before been imagined, to certain aspects of socio-cultural contexts. Examples of functions influenced or created by the cultural context are perception, self-appraisal, motivation, holistic or analytic information processing, and emotion [27]. The cultural dimension of individualism–collectivism has been shown to affect a diversity of higher psychological functions [27,28,29]. Individualism refers to when individuals construe themselves as separate from each other, whereas collectivism refers to when individuals construe themselves as highly interconnected, defined by their relations and social context.

Another potent cultural construct is holistic vs. analytic cognition, a dimension thought to characterize differences in thinking styles between Westerners and East Asians [30]. East Asians and Westerners apply different 'perceptual styles' to the task of decoding visual scenes. Westerners tend to focus on objects (in an analytical, context-free manner), whereas East Asians tend to focus more on contexts, relationships, and backgrounds [31,32].

A fundamental way in which culture shapes human behaviour is through self-appraisal, i.e., how people define themselves and their relation to others [27,29,30]. People from different cultures have divergent perceptions of the self. Individuals from Western cultures tend to value uniqueness and view the self as independent of others, whereas individuals from South East Asian cultures view the self as interconnected and interdependent with others. There are, however, huge individual differences [21], and in most modern cultures self-perception is not as dichotomized as was asserted for instance by Hofstede [33]. Due to the influence from modern individualistic cultures on traditional collectivistic cultures there has been proposed a construct of 'composite self' [34], or "bicultural self" which intricately integrates the traditional construct of interdependence with the Western construct of the independent and autonomous self [35].

The field of cultural psychology was according to Kitayama and Park defined by the following three guiding questions [3]:

(i). How does culture influence the human mind?
(ii). Is culture a crucial constitutive element of the mind? If so, what are specific mechanisms underlying this constitutive process?
(iii). What theoretical framework do we need in order to make visible progress in answering these questions?

In subsequent years, cultural psychology and cross-cultural psychology has provided insights into the first two of these questions by establishing a solid body of empirical knowledge. In spite of the progress in empirical knowledge about the impact of culture on most psychological functions there is still a need to develop a theoretical framework to *explain* the relationship between mind and culture more in detail and with theoretical intentions [36]. From what is now recognized about the multi-directional influence of genes, brain and mind, the interconnection of mind and culture also has to take into consideration the impact from human biology, especially the genes and the brain. Conclusive evidence for deep cultural impacts not only on psychological functions (mind), but on the very architecture of the brain is provided by cultural neuroscience [37,38], see below. Cultural-historical psychology contributes to an explanation of how culture is internalized and how the higher psychological functions are created on a biological and genetic substratum.

4. FROM GENES TO EPIGENESIS

The genes has until recently been looked upon as independent of the environment and culture. They represented the stable and inborn qualities in human beings, emphasized in contrast to the environment. The genetic outfit has been used to explain the inherited contribution to human psychology and behavior, signifying and expressing nature in the dichotomy versus nurture.

Researchers have searched for a long time for the genetic underpinnings of behaviour, mind or psychological functions. The Human Genome Project (HGP) was launched in 1990 and completed in April 2003. The HGP gave us the ability to read nature's complete genetic blueprint for building a human being. The mapping of the complete human genome created high expectations with regard to the potential of such research, for instance in psychology and medicine. Also psychiatrists become optimistic

and looked forward to reveal the genetic causes of severe psychiatric disorders. In the 1990s researchers in many countries hunted the "schizophrenia gen". But they become disappointed. Today it is acknowledged that the genetic contribution to cognition, emotions, psychological functions and disorders are so complex and context dependent that it can never be isolated one or a few genes responsible for disorders, behavior or higher psychological functions. It continues to prove quite difficult to identify genes for multifactorial traits (somatic or psychological) because most genes have such small effects and because their effects are often contingent on environmental circumstances [39]. The genes are themselves belonging to open systems endowed with remarkable plasticity to be molded by external and experiential influences as individuals behave and function throughout life in their respective sociocultural environments [40].

The genes also contribute of course to the specific development of the brain and mind, but they don't do it independent of the environment since the environment of the cell influences for instance which of the genes are expressed to affect cell characteristics. Also hormones and growth factors influenced by the surroundings turn some genes on and others off.In the field of biogenetics research there has been a recent shift from the traditional view of unidirectional gene-protein information flow [41,42] to a probabilistic-epigenetic framework emphasizing bidirectional interactions among genes, neuronal activities, behavior, and environment [43,44,45].

In recent years the inter-functionality between genes and culture has received intensive research effort [3]. A number of studies have demonstrated how experience (which becomes patterned by culture in human societies) 'gets under the skin' during the developmental process to influence genetic expressions, the brain as well as behavior [3]. For instance has the influence of the dopamine receptor D4 (*DRD4*) gene and caregiver quality on temperament in early childhood been studied [46]. The presence of dopamine receptor was associated with differences in the influence of parenting on children's activity level, impulsivity, and high-intensity pleasure.

Proponents of the new field of interpersonal neurobiology [47,48] argue that the structure and function of the developing brain are determined by how experiences, especially within interpersonal relationships, shape the genetically programmed maturation of the nervous system. Various genetic polymorphisms unevenly distributed across cultures seem to interact with local ecological environments (e.g. population density) and cultural practices like parenting to yield variations in psychological functions and brain pathways [46,49].

In contemporary genetics today intentional behavior cannot be reduced to the deterministic cause-and-effect level of a gene [50]. It is also unlikely that several genes in interplay will be able to ''cause'' complex behavior without input from the environment (i.e., certain kinds of experiences) and the higher psychological functions. The genetic influence on a complex phenomenon would have to be infinitely complex, involving all the developmental, environmental, social, and cultural influences that a human being is exposed to. Rutter observed that *First*, the genes may code for some polypeptide that is indirectly relevant but yet not involved in the main causal chain [51]. *Second*, not only are multiple genes affecting proteins involved, but also there are multiple genetic elements that influence the operation of any single gene affecting protein. *Third*, there are environmental influences on gene expression – the key process that determines the functional operation of genes. *Fourth*, some genetic effects are contingent on an interaction with specific environmental influences so that any understanding of the causal pathway must incorporate identification of the mechanisms underlying that interplay. *Fifth*, there will be influences operating on the pathway to the behavior that involve thought processes [51, p.174–175]. The higher psychological functions acquired from culture are therefore influencing how the genes "works", express themselves and affect body and mind (brain). The bi-directional relationship between biology and culture is therefore the principle to be applied to understand and explain human psychology. People are reflective beings and volatile. Intentional acts resulting from people's life experiences and the higher psychological functions including language and thinking, will, in turn, influence the expressions of their genes. In the words of Church: ''Not just from day to day, but from second to second, genetic cascades are turned on or off by our experience'' [52, p. 81].

4.1 Epigenetics and the Importance of Culture

Epigenetics is defined as ''the study of heritable changes in gene expression that are not due to

changes in DNA sequence'' [53, p.395]. Epigenetics studies the sources of expression or suppression of genes. In other words, ''Epigenetics studies the environment'' [52, p.48]. Epigenetics analyses how experiences effect genetic expression [54] and, according to Francis, ''Social interactions are a particularly important source of gene regulation'' [55, p.29]. Thus, much of what was presented above in terms of the importance of the environment or sociocultural context is epigenetics.

Although the concept of epigenetics was coined already in 1957 [56], it has only recently begun to appear in the psychological and medical literature. It is claimed that the traditional biomedical production of knowledge has hindered insight in the medical significance of peoples' experiences and that epigenetics will contribute to a holistic understanding of the relationship between body, mind, and spirituality [54]. In the words of Church: Yet our experiences themselves are just part of the picture [52]. We take facts and experiences and then assign meaning to them. What meaning we assign, mentally, emotionally, and spiritually, is often as important to genetic activation as the facts themselves. We are discovering that our genes dance with our awareness. Thoughts and feelings turn sets of genes on and off in complex relationships. Science is discovering that while we may have a fixed set of genes in our chromosomes, which of those genes is active has a great deal to do with our subjective experiences, and how we process them [39]. And the subjective experience, the meaning ascription is due to the acquisition of the higher psychological functions, especially the interconnectivity of thought and language that occur in the ontogenesis from 3-4years of age. People's experiences are thus biologically relevant in that they actually affect the expression of genes without altering the DNA. Experiences always occur in a unique socio-cultural context. Perhaps then, the ''new'' ideas from epigenetic research will contribute to a greater awareness of the crucial importance of culture in all psychological research, including biological research? This has already been seen in culture neuroscience (see below).

This section hopefully makes clear that culture is indeed crucial in psychological research, including research from a biological perspective. Reducing thinking, feeling, and behaviour to genes and the human's brain and disregarding sociocultural contexts, will impede us from understanding central dimensions of ourselves [57]. The words of Lewis-Fernandez and Kleinman have to be remembered: ''Psychiatry can no more afford to be context-less than it can afford to be mindless or brainless'' [58, p.444]. The same indeed applies to psychology.

5. BRAIN AND BRAIN DEVELOPMENT

Nearly all of the billions of neurons of the mature brain are produced throughout the fetal development and under the control of regulatory genes. The brain cells migrate to where they belong in accord with the functions they will ultimately serve [59]. Once the nerve cells are formed and finish migrating, they extend axons and dendrites and begin to form synaptic connections, often over relatively long distances. These connections allow nerve cells to communicate. The synaptic network undergoes its most dramatic development after birth, during the first few years of life. At its peak, the cerebral cortex creates an astonishing two million new synapses every second! As a child develops, the system of synapses become more complex, like a tree with more branches. By two years of age, a toddler's cerebral cortex contains well over a hundred trillion synapses. The period of synaptic exuberance varies in different parts of the cerebral cortex: it begins earlier in primary sensory regions, whereas the higher regions involved in cognitive and emotional functions are still rather primitive. Their development follows at a more leisurely pace, maximizing the opportunity for a baby's experience and environment to shape the emerging mind. The highest, most recently evolved part of the brain is responsible for all of our conscious thoughts, feelings, memories, and voluntary actions, what we call *higher psychological functions*. They are not determined by the genes during pregnancy, but by environment and culture after birth. These parts of the brain safeguarding the higher psychological functions are therefore heavily dependent on and influenced by the cultural environment.

5.1 The Interaction of Genes and Environment

Genes and environment interact at every step of brain development, playing different roles. Generally speaking, genes are responsible for the basic wiring plan, for forming all of the cells (neurons) and general connections between different brain regions, while experience or cultural environment is responsible for fine-tuning

those connections, helping each child adapt to the particular environment to which he/she belongs. For example, every human is born with the potential to learn a language. The brain is programmed to recognize human speech, to discriminate subtle differences between individual speech sounds, to put words and meaning together, and to pick up the grammatical rules for ordering words in sentences. However, the particular language each child masters, the size of his vocabulary, and the exact dialect and accent with which he speaks are determined by the culture in which the child is raised, that is, the thousands of hours it has spent (beginning even before birth) listening and speaking to others. Genetic *potential* is necessary, but DNA alone cannot teach a child to understand and use a specific language.

5.2 Brain Plasticity – the Brains Ability to Change

Two decades ago, medical professionals and neuropsychologists working in the field of neuroscience did not believe that the brain could change or that its capacity could improve in such a way as described above. The brain was looked upon as anatomically hard-wired at birth. Psychologists with other specialties than the brain did not know and hardly believed that the brain is capable of rewiring when influenced by the environment, for instance through the senses, or by using the language ability. Some years ago mainstream psychologists became uncertain and today there is lots of evidence telling that the brain changes its capacity, its structure and function, and that the brain actually is reshaped continually by being used and filled with cultural characteristics.

The brain never stops changing and adjusting, and it is not legitimate any longer to regard the brain as a fixed collection of wired-up neurons like the hardware in a PC. The structure and function of the “hardware” itself are changing [60].This model explains the importance of social and cultural influences since experiences are internalized and stored both in mind and brain [61]. Evidence for neuroplasticity abounds, - from the structural differences which have been found between people using different languages, to jugglers, letter sorters and those navigating a taxi in the twisting street of London, as described below.

5.3 Neurons, Neurotransmitters and Synapses

Communication between neurons is mediated by chemical transmitters, *neurotransmitters* that are released at specialized contacts, *synapses*. Synapses are the connecting points between the axon of one neuron and the dendrite of another. All of the *cognitive* information through which humans are able to reason, to think, to dream, to plan, to remember, and to do everything else that they do with their minds are transported between neurons and processed in neurons. A neural network is merely a group of connected neurons. The "best estimates" indicate that there are more than 100 billion and less than 200 billion neurons in the brain. And each of these neurons is connected to between 5,000 and 200,000 *other* neurons [62].

5.3.1 Synaptogenesis

In response to a new experience or novel information, neuroplasticity allows either an alteration to the structure of existing connections between neurons, or forms brand-new connections between neurons; the latter leads to an increase in overall synaptic density, a synaptogenesis, whereas the former merely makes existing pathways more efficient or suitable. In either case, the brain is remolded to take in new data. The new information or sensory experience is cemented into what seems to be the most useful and efficient location within the massive neuro-communicating network. Short-term exposure to an enriched environment leads to a striking increase in new synapses [63]. After birth environmental influence plays a key role in forging a denser and more complex network of interconnections. This is clearly evidenced by the rapid increase in synaptic density that can be seen in a normally developing human.

5.3.2 Neurogenesis

New research suggests that, beyond modifying pathways and forming new connections between existing neurons, the human brain also generate entirely new brain *cells* in some parts of the brain [36].While this neural regeneration was long believed to be impossible after age three or four, research now shows that new neurons can develop late into the lifespan, even of age 70 and beyond. Adult hippocampal neurogenesis declines however precipitously with age [64]. The neurogenesis happens in the *olfactory*

bulb and in *hippocampus* (http://www.thememoryworks.com/neuroplasticity/).

5.3.3 Genes and the brain

The development of the brain is determined by interaction of genetic programs and environmental events. Bartley, Jones & Weinberger who examined quantitatively the contribution of genes and environment respectively to adult human brain hemisphere volume and global cortical gyral patterns, concluded that human cerebral size is determined almost entirely by genetic factors and that overall cortical gyral patterns, though affected by genes, are determined primarily by no genetic, i.e. environmental and cultural factors [65].

6. CULTURAL NEUROSCIENCE (CN)

Cultural psychology and neuroscience have evolved as separate disciplines, but a closer look reveals that the two approaches are closely interrelated. Culture has therefore in recent years become a frontier for neuroscience and, conversely, neuroscience has also become a frontier for cultural psychology. The emerging field of cultural neuroscience (CN) has sought to combine theories and methods of the two disciplines [10,2]. CN examines how cultural values, practices and beliefs shape brain function, develops brain structure, and affects the neural architecture [66,67,32]. It represents a novel empirical approach to the study of bidirectional interactions between culture and biology by integrating theory and methods from cultural psychology [68], neuroscience [67,10,69,2] and neurogenesis [70,71,72].

Above we have seen how cultural and cross-cultural psychology has studied the differences in psychology due to sociocultural differences, for instance concerning individualism and collectivism. Despite rich understanding of how individualism and collectivism influence social cognition and other higher psychological functions, little was known ten years ago about how these cultural qualities modulate neural representation of psychological functions. Using functional magnetic resonance imaging (fMRI) and studying brain activity in different cultures and during specific cultural activity it is now evident that cultural qualities also are fastened in the brain [1]. The collectivistic and individualistic psychological biases also affect neural structure [1,73,74]. People who endorse individualistic cultural values show for instance greater medial prefrontal cortex (MPFC) activation to general self-descriptions, whereas people who endorse collectivistic cultural values show greater MPFC activation to contextual self-descriptions. Differences in cognitive processes related to processing information holistically (East Asians) or analytically (Westerners), and cultural preference for social hierarchy, are also accompanied by differences in brain structure [75].

More generally, research investigating the neural foundations of cultural phenomena has discovered that sustained exposure to a set of cultural experience and behavioral practices will affect neural structure and function [74] and that human culture is manifested in neural activation patterns. Conclusive evidence for deep cultural impacts not only on cognition and psychological functions, but on the very architecture of the brain is provided by CN [37,38]. "… The neural activity in some brain areas strongly depends on a person's cultural background" [2, p. 652]. To the extent that sociocultural practices diverge, so will psychological functions [24,76], leading to neural specialization of acquired abilities [77].

6.1 Recent Examples of CN Results

6.1.1 Perception

In a fMRI study [32], Chinese and American participants judged various pictures of objects, backgrounds, and their combinations. Consistent with prior studies suggesting greater object-focused processing among Westerners, American participants (compared with Chinese participants) demonstrated stronger and more distributed neural activations during object processing. The neural substrates of human *perception* might seem more or less universal. However, recent research has revealed a set of cultural differences in the neural mechanisms subserving various perceptual domains, including object processing, color discrimination, and taste [6].

6.1.2 Different language create different brains

Also differences in language and orthography can be seen in the brain. Fluent reading of Western alphabetic languages, such as English, requires relating visual forms to sounds, whereas reading logographic languages, such as

Chinese, whose characters do not have specific phonetic analogues, relies more heavily on associations between visual forms and meanings [78]. These orthographic differences demonstrably result in different neural structures being important for reading different languages [6]. The brain activity of native English speakers is different from that of native Chinese speakers [79]. The findings could be attributed to exposures to different visual patterns owing to the visuospatial nature of the Chinese language and activation of language areas for English speakers.

6.1.3 The self in the brain

One of the first social-cultural topics to be explored in CN was how people represent the self [79]. Across a wide range of studies, including both Western [80] and Eastern [81] participants, an area of the ventral mPFC/anterior cingulate cortex (ACC) activates more for thinking about the self, compared with thinking about other people. However, given cultural differences in self-other construal, particularly differences in Western independent views of the self as distinct from others and Eastern interdependent views of the self as fundamentally related to others [27], also emerge at the level of the brain. To test this hypothesis, Westerners and Chinese participated in a study that included thinking about both the self and a close other (one's mother) during fMRI scanning [82]. Consistent with prior work, ventral mPFC (and perigenual ACC) responded preferentially to the self for all participants. However, thinking about one's mother elicited preferential activation in the ventral mPFC only for the Chinese participants. This finding [82] supports previous theoretical assertions that Easterners view close others (and their relationships to those close others) as part of the self, whereas Westerners tend to conceive of the self as an independent entity [27]. Representation of self shapes neural activations, making a compelling case for cultural values determining neural function [3,74]. Western individuals with an individualistic self-perception have a different brain structure compared with East Asian's i with an interdependent self [1,81,82,74].

6.1.4 How juggling and taxi driving changes the brain's structure

There is a wealth of evidence that motoric activity and experiences sculpt brain and behaviour. Recent work in cognitive neuroscience has provided clear evidence that sustained experience changes neural structures. London taxi drivers who engage in sustained route finding show more grey matter in the posterior hippocampus, with the magnitude of the effect increasing with experience, suggesting experience is the causal mechanism [83]. Canadian postal workers spend thousands of hours sorting postal codes by letters and numbers jointly, and this experience changes the categorical representation of these two symbolic systems into a single more unitary system in the brain [77]. Sustained practice in learning to juggle increases the volume of cortical tissue in the bilateral mid-temporal area and left posterior intraparietal sulcus [84].

6.2 Some Methodological Considerations

CN, as well as cognitive, social and affective neuroscience, has developed an arsenal of techniques for mapping neural processes to cultural activity and psychological processes [9,85,67]. About fifteen years ago functional magnetic resonance imaging (fMRI) studies were published for the first time in order to investigate the impact of culture on the brain [86]. Since then the number of publications using this procedure has increased tremendously. fMRI is a technique for register brain activity in a particular place. However, register the location and may be intensity of brain activity does not reveal the mind-brain interaction or the connection between the external world and the inner psychological world. The mind is seldom dealt with at all. It should not be of any surprise that there is an activity in the brain representing physical and mental activity; for instance that babies' brains change when they learn their native language [87]. The localization of brain activity does not however, give much information about *how* the acquisition of language takes place, or explains the relationship between mind, brain and culture. The mind-brain relationship has to be explained in a theoretical manner, and in this article Vygotsky's cultural-historical psychology presented in the next section provides some suggestions for how acquiring of culture in mind and brain can be explained and understood.

6.2.1 Localization of functions

Restak has referred to brain-imaging studies as neo-phrenology [88]. Where the old phrenologists measured peoples' skulls the brain-imaging people measure inside peoples' skulls. Restak further maintains that the brain

patterns involved in complex behavior involve multiple circuits that are spread throughout wide parts of the brain and that they vary from one person to another. ‘‘That’s why it’s so risky and often just plain wrongheaded to attempt too rigid a localization of complex and multi-determined behaviors to specific locations within the brain’’ [88,p. 203]. Those unfamiliar with the neurosciences tend to hold an oversimplified idea of functional localization which is promulgated by misrepresentations of scientific work in the popular media [89]. Yet, the empirical evidence is more consistent with the view that psychological states and processes are mediated by a network of distributed, often recursively connected, interacting brain regions, with the different areas making specific, often task-modulated contributions [90,91]. If a single brain area is found to be activated by a task, it does not necessarily imply that this region is the seat of the information process supposedly tapped by the task; instead, it suggests only that this region may be part of a widely distributed network jointly responsible for the observed process.

Nevertheless, current CN provides evidence for the assumption that the brain is altered by learning and experience, organized by culture and it articulates the multidirectional relationship of the psychological, neural and genomic processes and their emergent properties [67]. It takes as its starting point what Keller has formulated: “The important message is that social interactions among humans shape neural connections, i.e. the fine-tuning of the brain, as well as the mental representation of experiences and thus the psychological foundation of the individual…these interactions occur at a variety of neurophysiological and behavioral levels and are domain specific” [92, p.216].

7. LOWER AND HIGHER PSYCHOLOGICAL FUNCTIONS IN MIND AND BRAIN

The first part of this section presents the development of higher psychological functions. The presentation is inspired by Vygotsky’s cultural-historical psychology and his distinction between lower and higher psychological functions. The second part suggests how lower and higher functions are represented and established in the brain. The issue is based on what is presented about genesis and epigenesis, development of the brain, synaptogenesis and cultural neuroscience earlier in the article.

7.1 Psychological Functions

The cultural-historical psychology was founded by the Russian psychologist Lev Vygotsky in the 1920s. He and his Russian colleague Alexander Luria criticized their fellow countryman Ivan Pavlov for not studying the most important subject in psychology: the human consciousness. Pavlov’s work was, quite literally, “thoughtless”. To reveal that animals could be conditioned to learn through associations did not expose the specific in humans: the capability to think, to use language, to behave volitionally and to adhere to cultural norms and values [93]. “Pavlov’s theory stopped short of the higher forms of behaviour, the forms inherent in man the personality, not just man the organism” [94, p. 216]. Although the term “reflexes” (conditioned and unconditioned) applies to animals as well as to human beings, the difference is that they are sufficient to explain behavior for the former but incomplete for the latter.

Vygotsky was particularly concerned with developing an approach to psychology which accounted for consciousness. In doing this he distinguished between lower, elementary (or natural) psychological functions, characteristic of animals and young children, on the one hand, and higher, or cultural psychological functions [95,96], more characteristic of older children and adults, on the other. The lower functions are instinctive mechanisms, such as blind reactions to stimuli, basic processes of sensation, memory, attention, as we would see in all animals. They do not involve any conscious awareness of mental processes. To be a human, however, means to reduce the automatic, instinctive behaviour and become a conscious being, able to decide, choose, and think with language as a psychological tool. The higher psychological functions are created by the individual in cultural/social interaction and communication. They are unique to every individual, depending alike on genetic features, lower psychological functions and socio-cultural experience.

According to cultural-historical psychology, biological phenomena (genes, hormones, brain) provide the framework for human psychological phenomena rather than directly determining them. This leaves psychological activity as something to be built up from, rather than reduced to biology. To be human means to have surpassed a level of functioning biological traits would otherwise dictate [97] The genetic or instinctive driving forces are overruled by what is

acquired during socialization in a particular culture. The number of human activities under biological control is greatly reduced in comparison with (other) animals. Conscious behaviour is only possible if the elementary lower functions are set aside from their original function. Biology has therefore lost it determining function in human behaviour. To live in a human constructed culture calls for socially constructed, designed, voluntary, volatile behaviour. The automatic, elementary functions have, however, not disappeared but they have changed their function and importance as they may mingle with higher cultural functions. There is an inter-functionality between the organic maturation driven by biology and the cultural learning which characterizes the emerging and development of a child in a culture [93]. Human are created by a culture that they have created, and their psychological functions acquired in a culture using symbols and signs (language). “Most basic is the fact that man not only develops naturally; he also construct himself” [9, p. 65]. The human mind is therefore socially mediated: “Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (inter-psychological) and then inside the child (intra psychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All higher functions originate as actual relationships between individuals” [76, p. 57].

But if human psychology is social and cultural determined, does this mean that the individual is reduced to an automaton that passively receives social influences? Quite the contrary. The impact from the environment is filtered through individual, idiosyncratic stored experience in mind and brain: «The child begins to see the external world not simply with his eye as a perceiving and conducting apparatus-the child sees with all of his previous experience..." [15, p. 148]. Sociological reductionism ignores the proper inner logic of the transformations which a child’s inner life goes through with the change of the “season of life” [94, p. 277].

7.2 Animals and Humans

Elementary natural functions operate in different ways from cultural conscious functions. This is why the former cannot govern the latter. They cannot even serve as the basis of the latter. “Higher psychological functions are not simply a continuation of elementary functions and are not their mechanical combination, but a qualitatively new formation that develops according to completely special laws and is subject to completely different patterns” [98, s.34].

Biology changes its role in psychology from animals to humans. It does determine animal behavior in natural environments but changes to a potentiating, energizing function with regard to human psychology. The key to human’s psychological functions is sociogenesis (the transformation of socio-cultural relations, though interiorization to the individual’s psychological functions). The young child is a pre-cultural biological organism which becomes transformed by cultural signs such as language, into a cultural being and thereby acquires higher psychological functions overruling the elementary functions which directly impel behavior without any conscious reflection [93]. “Natural processes, for example, operate in hummingbirds to automatically impel them to fly toward red colored flowers; or they impel male dogs to involuntary and mechanically mount and mate with a female dog that emits a particular scent during her fertile period. Hummingbirds and dogs do not think about what they are doing, they cannot control it, they cannot plan it or imagine it, or remember (relive) it in specific details; they do not appreciate the object of their behavior, as a human male appreciates his sexual partner or appreciates a beautiful sunset or painting. This is why elementary natural processes cannot determine psychology in the way that they determine behavior of birds and dogs” [99].

Human’s mind is characterized by “*doubling experience*”, meaning that human can consciously represent (in mind) the goal of his/her activity. In using this term, Vygotsky referred to Marx:

> *But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality. At the end of every labor process we get a result that already existed in an ideal form, that is, in the imagination of the laborer at its commencement* [100, p.103].

The “doubling experience” is qualitatively different from ordinary reflexive behaviour and dependent on acquisition of language. The mechanism of a reflexive reaction is triggered by the stimulus of å word. Language is more than a tool for thought. The word also has a volitional function. Humans’ locomotive apparatus is subordinate to it. The word and verbal language

has power over the real actions of humans' bodily structure and their psychological functions [94]. "Because a verbal stimulus may be reproduced, this is, become a response, and that response may in turn become a stimulus, the reflexes become reversible" [101]. Culture is "responsible" for this human ability.

7.3 Mediation by Language

Higher functions involve some kind of mediating processes between stimuli and reaction. While this mediation may be as simple as tying a string around one's finger to help remember something, it may be as complex as an entire linguistic or symbolic system such as that of language or mathematics to help in problem solving. Words and language are the prototype of mediators.

Human biology and especially the brain, developed through evolution made thinking and language appropriation possible [93]. Nature therefore predisposes us to learn and acquire higher psychological functions using language as a tool, whatever culture we are born into [102]. The greatest drama of ontological development was played out in the very first words of a child – this period illustrates and represents the conflict between the natural and the socio-historical [94]. Language is not created by the subject. It exists independently of it. The task with which the subject is concerned is the use of a ready-made sign system (not one she/he creates on his own) in communication, cognition or action. Not only is language acquired in a socio-cultural setting but all manner of behavior and psychological processes occur first in social situations. As soon as speech or signs are involved in action, the action is transformed and organized along entirely new lines, in mind and in the brain.

7.4 Lower and Higher Psychological Functions in the Brain

There are important differences in how the brain represent and take care of the lower elementary, instinctive functions, created early, during pregnancy, - and the higher psychological functions, for instance the language functions. The latter ones are both as a mind function and in the brain more complex, involving several parts of the brain, activating more neurons and creating more connections between neurons, often far away in the brain.

Before birth the brain has not established the network or pattern representing cultural activity, especially not the network embodying the language and volatile, consciousness capability. Lower psychological functions are the natural, instinctive functions not involving language, signs or thought. These psychological functions are structured in the neural network by the genes during pregnancy, and nearly independent of environmental, cultural influence. This mind state is represented by temporary networks dependent primarily on the genetic outfit. The only brain structure which is developed to anything like its mature form at birth is the lower brainstem. This part of the brain controls the primitive reflexes and vital functions such as respiration and the cardiovascular function. The lower brain is largely in control of a newborn's behavior: all of that kicking, grasping, crying, sleeping, rooting, and feeding are functions of the brain stem and spinal cord. Even the striking visual behavior of newborns, their ability to track a bold moving object, like a red ball of string, or to orient to Mom or Dad's face, is thought to be controlled by visual circuits in the brain stem.

Immediately after birth, baby's higher brain regions begin to make billions of connections between neurons all over the brain. Stimulation through the senses of touch, hearing, vision, smell and taste, in addition to vestibular and proprioceptive experience, directly influence the neurons and is the origin of the new synaptic connections. The higher psychological functions are represented by complex brain structures, networks established as a result of sociocultural activity – particularly important is the acquisition and development of language, words and concepts in combination with thinking.

So what about genetic factors? The genes have, at birth, laid down the mental roadmap neurons must follow and built its major "highways" between the basic areas of the brain [93]. Environmental and cultural influence plays the key role in forging a denser and more complex network of interconnections. The smaller avenues and side roads makes the transfer of information between neurons more efficient and rich with situation-specific details. At birth, each neuron has approximately 2,500 synapses or connections. By the time we have reached 2-3years of age, sensory stimulation, environmental experience and language acquisition have taken full advantage of the brain's plasticity; each neuron now boasts around15,000 synapses in average [103], and the higher psychological functions are created by the culture-driven synaptogenesis, not solely the genes.

Since the brain 'natural' or 'biological' structure is changed due to cultural impact there is no clear dividing line between the 'natural' and 'cultural'. Cultural differences are persistent because the native culture is fastened in the brain. It becomes 'second nature' seemingly as 'natural' as the instincts we were born with. The biologist T.C Schneirla claims: "It is valid to speak of a 'worm nature', an 'ant nature' or even a 'bird nature' but not of a 'human nature', for man can have whatever nature the conditions of his rearing and social situation permit" [104, p. 30-85]. We do not distinguish our 'second nature' from our 'original nature' since the brain, once rewired, develops a new second nature, every bit as biological as the original [61]. There is no hardwired 'nature' in the brain that last a lifetime. The distinction between nature and culture is not easy to draw on the psychological level either, partly because the cultural becomes natural in the brain's structure.

In the process of the formation of the higher psychological functions, the structure and brain organization undergo transformations with a simultaneous modification of their reliance upon inborn biological mechanisms: Initially, these functions are determined by biological mechanisms, but in a later phase, the higher functions assume control over biological mechanisms by integrating the lower ones into their neural network.

7.5 How Language and Thought is Stored and Influence Brain Structure

We have to separate two kinds of socio-cultural impact and also two kinds of higher psychological functions as well as brain activity. The first kind is the same for animals and humans, due to activity and sense experience in a natural and socio-cultural environment. Both mind and brain are influenced by the environment, enabling broader ranges and behavior influencing neurogenesis and synaptogenesis. This happens for both animals and humans. The other kind of socio-cultural impact is linked to psychological tools, especially to language and signs, and the human ability to combine language and thought. Language capacity and thinking involves more neurons in different parts of the brain and new neural connections and networks have to be established.

The higher functions are fastened in the brain as a result of synaptogenesis after birth. The growth in brain structure and therefore development of the brain function is due to cultural activity either with, or without language and other cultural signs, becoming psychological tools. The growth of the brain (the synaptogenesis) improves the acquisition of other psychological tools and increases the domain of higher psychological functions both in mind and in brain. When the brain establish new connections between neurons and make a denser network of brain cells, this changing of the brains structure and function also makes it easier to create and acquire new cultural facilities in the next round. The area of the higher psychological functions in brain and mind will develop and increase at the expense of the lower, elementary, instinctive, non-volatile functions. Their synapses will be pruned and substituted with more complex neural networks, also including the former representing the lower functions. Brand new constellations emerge in the brain when neurons are connected making a new functional structure representing development in the mind.

According to Akhutina we must not view mind as [consisting of] special processes which supplementary exist on top of and alongside the brain processes, somewhere above or between them, but as the subjective expression of the same processes, as a special side, a special qualitative characteristic of the brain activity [101]. The higher psychological functions using cultural/psychological tools like language cannot be developed without input from the cultural environment and the brain structures representing these functions are therefore a result of communicating activity in a cultural setting, predominantly after birth (There are some impact from language acquisition already during pregnancy, but compared with what happens after birth, at 2-3 years of age, this pre-birth impact can be ignored).

When a child acquires the first language at 2-3 years of age the synaptogenesis is particularly active or fluent. It is created up to 2 million synapses every second in this period, and it is assumed that many of the new connections established between neurons represent language ability, the mediating system of the mind and brain. The acquisition of language is in the beginning a storing of words from the vocabulary of the family members or other in close connection to the child. Afterword/subsequently the words are combined with the ability to think and the brain structure is adjusted to the new function of the thinking/language combination. The child starts

thinking by words and after a while also by concepts and these psychological tools are used for thinking. This development of the mind, consciousness and higher psychological functions takes place also in the brain by developing new neural patterns.

The lower, instinctive or non-volatile functions established by genes during pregnancy and only to a minor degree created by environmental/cultural influence (except for the influence on the genes function, the epigenesis during pregnancy) will also be changed when mind and brain are developing the higher, language- or sign-based functions. Their “pure”, original fashion will be transformed by the influence of the higher functions and both in mind and in the brains structure they will cooperate and be dominated by the fast growing higher functions. Most of the new neural patterns of the brain belong to the higher psychological functions and the functions representing language and sign are of particular interest for human beings, since no other species have the same ability to combine language and thinking.

7.6 Genetic and Cultural Evolution

Much behavioral diversity in human populations cannot be accounted for by the genes. Conventional evolutionary biology theory posits that organisms adapt to their environment and over time exhibit favorable traits or characteristics that best enable them to survive and reproduce in their given environment through the process of natural selection [105]. The concept of natural selection has been enormously influential to the study of human behaviour, particularly in evolutionary psychology, which has emphasized that much of human behaviour arises as a by-product of adaptive mechanisms [106]. More recently, culture-gene coevolution (see above) has emerged as an influential theory to explain how human behaviour is a product of two complementary and interacting processes: genetic and cultural evolution [107,108,109. Jahoda also underline the co-construction by biology and culture: “.., the former sharp distinction between biology and culture is giving way to the recognition of their interrelationship, though exact nature as well as its significance for development remains as yet controversial; and so does the question as to the extent to which aspects of development are pre-programmed” [110]. The brain serves as a crucial site that accumulates effects of cultural experience, and neural connectivity is modified through sustained engagement in cultural practices. Thus, culture is "embrained" and human evolution become dependent on culture more than nature [38].

Vygotsky also formulated this as a radically new idea. He spoke on a new form of evolution with reference to human beings only:

> The whole question is *what* it is in the brain that physiologically corresponds to thinking in concepts. In order to explain its development in the brain, it suffices to assume that the brain contains the conditions and possibilities for a combination of functions, a new synthesis, new systems which do not at all have to be structurally engraved beforehand [111, p. 128].

If translated into modern concepts, that mean that the evolution of animals implies a change in *hardware*, that is, a material repository of programs; the development of man implies mostly a change in *software*, a flexible, easily modified system of programs [101]. That program is governed by the higher psychological functions.

Vygotsky also postulated a new principle of localization of functions in the human brain as compared to the animal’s brain. It refers to the specifically human brain areas (frontal and parietal associative zones) and to the specifically human types of activity, “higher forms of speech, cognition, and action” [111, p. 174]. Vygotsky emphasized that “extra cerebral links” play a significant role in the process of formation of these functions: “This history demonstrates that initially all these functions operate in intimate connection with external activity and only later on, as it were, disappear inward and change into inner activity” [111, p. 174). That statement of Vygotsky about a social way of forming higher psychological functions during one’s lifetime, while being closely related to the principle of localization, was acknowledged in neuropsychology as a principle of social genesis and a mediated structure of the higher psychological functions [101].

7.7 Mind, Consciousness and Brain Neuroplasticity

Brain plasticity and synaptogenesis verify that the brain is not structurally determined, but permanently changing, and it therefore contains the conditions for developing word meanings and concepts and that higher psychological function are represented by complex systems of the

entire brain, acquired during cultural activity and communication.

Brain plasticity is relevant for an understanding of consciousness as something not static. The contents of consciousness are constantly changing and developing through our experiences and through our sharing of experiences with others. In contemporary consciousness studies the phenomenon of neuroplasticity has however received little attention despite the fact that neuroplasticity is of still increased interest in neuroscience. Studies of the development of consciousness should be carried out in the future to enhance the knowledge of how neuroplasticity have impact on neuroplasticity and if consciousness is connected to specific brain processes. It seems that the ability of the neural structures to change may have consequences also for the character and content of consciousness and it has to be studied in the future how development in brain structure can literally change the way a person is conscious, and how development of consciousness is supported by synaptogenesis in the brain. To follow the development of the cells and the establishing and pruning of synapsis could give more detailed knowledge of the processes. To study such phenomenon it is important for the fMRI studies to move beyond simply identifying brain regions that are differently activated by a task and include structural and functional connectivity mapping as well as dynamic recording of neurogenesis and synaptogenesis. To study empirically whether the lower functions are pruned or outnumbered when higher function synapsis are established would also be an important task in future research as well as clarifying what is actually cultural tools and how language tools are different from other cultural/psychological tools.

8. CONCLUSION

Culture is fastened in the mind and brain and represented by the higher psychological functions. They are unique to every individual, depending alike on genetic features, lower psychological functions and socio-cultural experience and communication, embodied by neurons all over the brain, connected with synapses created after birth.

COMPETING INTERESTS

The author has declared that no competing interests exist.

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