14th Annual International Conference on Kinesiology and Exercise Sciences 30-31 July & 1-2 August 2018, Athens, Greece
Maria Rosaria D'Acierno Associate Professor University in Napoli Italy

Physical Education between body health and cognitive growth for young children (age 3 to 5).

Key words: physical exercise, mental health, irisin, muscle memory, neuroplasticity, muscle memory, cognitive growth, senescence.

Abstract

This study, based on the observation of children (3 – 5 year olds) following a program of specific physical exercises guided by music, wants to evaluate the effect of movement on body, mind and cognition. It will promote activities and experience in order to 1) build up a healthy body and a healthy mind; 2) prevent obesity as well as type 2 diabetes, and 3) to improve "the functions of the liver, muscles themselves, and (importantly) the brain," as attested by the essays edited by B. Spiegelman, which report the results of the metabolism related to people regularly practicing physical education. By taking into account the last researches about the stimuli the brain receives from a rich environment and their impact on the activation of neural plasticity, which is more elastic during childhood, this analysis aims at stressing that the hormone irisin, whose beneficial effects on our health belong to the latest studies on physical exercises, is of great help not only to build up a healthy future life, but also to cure some diseases due to age or occasional accidents.

> Exercise has been understood for centuries to provide benefits to the human body. Diet and exercise have long been prescribed as the first lines of therapy for metabolic diseases.[1]

> The many benefits of physical exercise to human health are widely recognized. Depending on their type, intensity, duration and frequency, different exercise modalities can be used to improve diverse physiological parameter. These include cardiovascular fitness, strength, energy metabolism, and resistance to fatigue, among others. Importantly, exercise training can be used as a prophylactic or therapeutic intervention for a variety of pathologies ranging from obesity and diabetes to cancer and mental health disorders. Indeed, maintaining an active lifestyle continues to be the best way to promote healthy longevity. [2]

> A recent study investigated the neuroprotective potential of irisin treatments in cerebral ischemia. Irisin improved survival of cultural PC12 neuronal cells in oxygen glucose deprivation. … Systemic irisin administration has also been shown to ameliorate depressive-like behavior in a chronic unpredictable stress model in rats.[3]

> Lifestyle intervention such as regular physical exercise is widely recognized to improve whole-body performance and metabolism in health and disease. An increase in daily physical activity is an effective approach to combat many disease symptoms associated with metabolic syndrome. Endurance exercise can improve insulin sensitivity and metabolic homeostasis.[4]

---

[1] Spiegelman B. (eds), *Hormones, Metabolism and the Benefits of Exercise*, Springer International Publishing, Switzerland, 2017: 47.
[2] Valente-Silva P. and Ruas L. J. Tryptophan-Kynureine Metabolites in Exercise and Mental Health, in Spiegelman (eds.) 2017.
[3] Wrann C. D., The Role of FNDC5/Irisin in the Nervous System and as a Mediator for Beneficial Effects of Exercise on the Brain, in Spiegelman (eds.) 2017:
[4] Benoit Viollet, The Enegy Sensor AMPK: Adaptations to Exercise, Nutritional and Hormonal Signals, in Spiegelman (eds.), 2017.

> … the biggest precursor of insulin resistance (high blood sugar) is loss of muscle resistance … weight training is way more effective in controlling and getting rid of diabetes than hypoglycaemic drugs … but you will have to be regular with it as you are with your medicine. … Our muscles in response to exercise release Cytokines (protein-like) which control blood sugar and may ever lead to the muscle cell being qualified as an endocrine organ.[5]

1) Introduction

My research addresses the issue of pointing out that physical education early learning experience is a good opportunity children have to prepare their body and their mind for an active and healthy future life. This analysis considers both the psychological and physiological assumptions, because it wants to clarify how stimuli change and even enlarge the size of the brain. Gray matter can actually shrink or thicken, it all depends on the kind of phenomena affecting it. Fitness and exercise is considered a good input for the brain from both the physiological and psychological point of view, so, it increases the gray matter volume in multiple regions. Under the hypothesis that there is a connection between body and mind, Kramer consideres physical movement as one of the most important fields to be analysed, thus establishing that "Across the board, exercise increases brain function, memory retention and other key areas of cognition up to 20%." In his article, in which he reports the results of a program of physical exercise (65 to 80 year olds), an experiment run to prove the advantage of movement, he affirms that even though "after the third decade of life the human brain shows structural decline, … cardiovascular exercise has been associated with improved cognitive functioning in aging humans. These effects have been shown to be the greatest in higher order cognitive processes, such as working memory, switching between tasks, and inhibiting irrelevant information, all of which are thought to be subserved, in part, by the frontal lobes of the brain."[6]

Under those hypotheses, my project is mostly based on the role new inputs have in organizing the brain and its functions, when it receives as many stimuli as possible. This study, by emphasizing that children acquire notions more rapidly compared to adults, does not want to say that adults cannot face new knowledge, which, rather, are a valuable resource at any age, and even after injury for both the physiology of the brain and the plasticity of behaviour, as attested by Aage Møller when he talks about dementia, and how to prevent it or slow down its consequences: "Physical and intellectual activities slow the age related deterioration of the heart and the blood vessels and thereby preserve good blood supply to the brain."[7]

> Although the property of brain plasticity is most obvious during development, the brain remains malleable throughout the life span. It is evident that we can learn and remember information long after maturation. Furthermore, although it is not as obvious, the adult retains its capacity to be influenced by 'general' experience.[8]

In this essay, the issue of physical exercise has been afforded from various sides: 1) the examination of the different parts of the brain and their functions derived by the notion of neuroplasticity; 2) the role of memory, especially the one related to skills, and the importance of the 'mirror neurons based on imitation during the development of language and thought, as analyzed by Piaget, Vigotskij and Lurija, in the phase in which imitation and self-instruction guide the child to develop a series of activities. Then, it has been considered 3) muscle memory during the process linked to the acquisition of physical exercises, and 4) the importance of irisin hormone induced by physical exercise in order to promote bone formation muscle strength, and to reduce food intake. I do not want to restrict this analysis at the critical period as experimented, principally

---

[5] Diwekar R., *Strength Training*, Westland Publication, New Delhi, 2014: 36, 102, 86.
[6] Kramer A. F. et al., Aerobic Exercise Training Increases Brain Volume in Aging Humans, in *Journal of Gerontology: MEDICAL SCIENCES*, Vol. 61A, No. 11, 2006: 1166-1170.
[7] Møller Aage R., *The Malleable Brain*, Nova Biomedical Books, New York, 2009: 173.
[8] Kolb B., *Brain Plasticity and Behaviour*, Lawrence Erlbaum Associate Publishers, Mahwah, New Jersey, 1995: 5.

in the field of language acquisition, by Lenneberg, Penfield and Roberts, in the last century. They attested that the best time for a child to acquire new notions happens from birth up to 10/11 years of age. After that critical period (or sensitive or optimal hypothesis), the brain loses its plasticity. As a consequence, it seems very difficult to add new knowledge. Under the premises of recent studies, I believe that any age has the privilege to acquire whatever we think is a benefit for our psychological and physiological growth,

> "It is generally known, and is beyond dispute, that focal lesions in young children carry a prognosis different from that of similar lesions in adults. Pathology confined to the left hemisphere and incurred before the end of the second year of life does not block language development, which might even occur at the normal age. If the insult occurs after the onset of language development, but before the end of the child's first decade, a transient aphasia may ensue, but if the disease is arrested, language is fully recovered within a year or so, even though the left hemisphere may have a fixed and irreversible lesion."[9]

> "The use of language depends on the functioning of two unilaterally localized 'speech areas' in the 'dominant' hemisphere of the brain. These speech areas, and especially their unilateral location, are not based on genetically predetermined structures, but they develop functionally in one of the genetically equipotent hemispheres during childhood and in apparent simultaneity with the acquisition of speech."[10]

Bryan Kolb, when examining the role of plasticity, known as the Kennard Principle, in both infants and adults, points out "two fundamental problems" related to his hypothesis, which even having "some intuitive appeal, because it is a common observation that infants seem to recover quickly from many maladies, and because their brain is developing, it seems reasonable to expect that it would be able to compensate better than the adult brain. In fact, it is rare for children to experience lasting aphasia, which is a major problem for adults with left hemisphere injuries, and various authors have used this observation as evidence for plasticity in the infant brain," results unreliable for "two fundamental problems."

> First, the idea assumes that all developing brains are equivalent. We have just seen, however, that the brain goes through several stages in development, and it is a very different brain in each stage. It seems likely, therefore, that brain injuries will have different consequences at different stages of brain development. Second, the Kennard principle ignores the fact that development of the brain is much like building a house. You must begin with a foundation, then progress to the framing, and so on. … The idea that there is an important, and necessary, sequence in both brain and cognitive development was first clearly stated by Hebb, and thus I take the liberty of calling his idea the Hebb principle. Hebb was studying children with damage to the frontal lobes in infancy, and he concluded that brain damage early in life may be worse than later damage because some aspects of cognitive development are critically dependent on the integrity of particular cerebral structures at certain times in development. In other words, if certain structures are not working properly during critical periods in development, it may be that cognitive development is adversely affected and the child is never able to adequately compensate.[11]

New researches evidence that foreign languages as well as new inputs in any branch of knowledge, can be acquired at any age, of course with certain limits especially if the learning context is not stimulating and not very well planned. These studies emphasize how new experiences alter the structure of the brain due to its plasticity, either if related to a specific period

[9] Lenneberg E.H., In Search of a Dynamic Theory of Aphasia, in *Foundations of Language Development*, Academic Press, New York, 1975: 12.
[10] Bay E., Ontogeny of Stable Speech Areas in the Human Brain, in *Foundations of Language Development* (eds by Eric Lennegerg and Elizabeth Lennegerg), Academic Press, New York, 1975: 21.
[11] Kolb B., *Brain Plasticity and Behavior*, Lawrence Erlbaum Associates, Publishers, Mahwah, New Jersey, 1995: 76.

of time or to other conditions. The brain maintains, during life, its capacity to react to both environmental changes and changes happened within the organism itself (hormones, diseases, strokes, etc.); so that, it can adapt to new situations. Of course, childhood remains the best age in which it is possible to construct a better and richer lifestyle, not excluding that external as well as emotional stimuli increase the plasticity of the brain at any age, as experimented when an accident damages some of its capacities, later recovered through specific treatments. Within these new theories, physical education becomes a vital exercise to be introduced at any age. Children have the advantage that, by practicing physical education at a very early age, they will not only build up safe and healthy habits, but, moreover, they will enlarge their cognition, while acquiring permanent healthy behaviour.

My experiment has been developing for various years (since 2015). We have followed an extemporal observation on how teachers expand Physical Education within the school curricula, and how they link it to the other subjects. The observation has been carried out specifically in the Italian Primary and Middle school. The pupils we observed (3 to 13-year-olds) had been facing an important period of their growth from both the physiological (plasticity of the brain) and the psychological side (plasticity of behaviour). In fact, the kindergarten and pre-school children, at that age, experiment the development of their body, first of all, while the middle school pupils add a great deal of academic knowledge. This analysis, in particular, considers the value of physical exercises for children at kindergarten. It wants to stress that a healthy life-style as well as a natural nutrition habit gives children the opportunity not only to grow up in good health, but above all to live a more active life from both the physiological and the psychological side. At the beginning of the school year (from September up to May), we decided to interact with a group of children (10), aged 3 to 5, everyday for half an hour, asking them to develop a series of physical activities. The control group followed the schedule as established by the school curriculum. The very young children in the control group were not expected to practice any properly organized physical activity, unless some games. The others, five years, had physical education only two times a week for less than one hour.

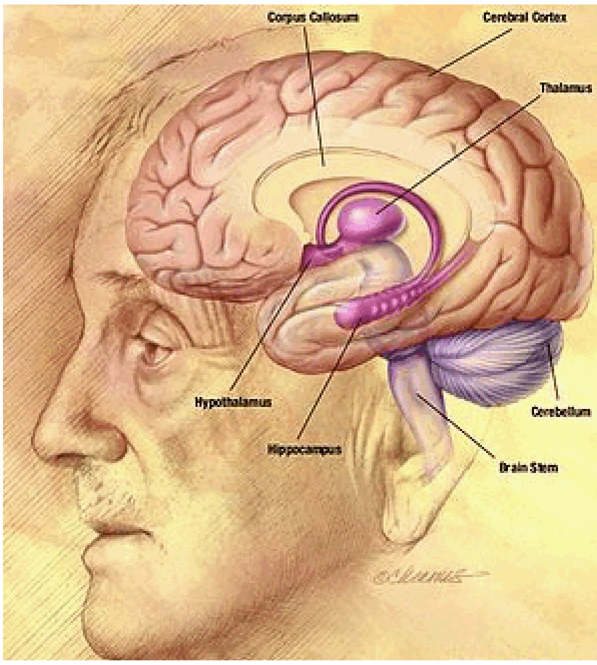
Conclusions are hard to draw, unless that children enjoyed moving in groups while listening to music, at last maintaining a certain rhythmical balance between music and exercises. This program cannot be valued soon after the experiment for many reasons.

1) First of all, because the children were very young, and they themselves did not realize the importance of this physical education course;
2) then, because, in any case, their physiological growth followed their own time, and
3) third, because we cannot know if improvement in motion happened only because of an added program of activity.

The results would have added more value if some children in the group had showed some genetic inability. For this reason I have planned to go on with this research in order to really consider time, as well as physiological and psychological development. Only a pale consideration might be added, the one related to the joy the children showed when they exercised according to the rhythm of the music. They often tried to follow the tune of the songs by moving their arms and their body synchronically. Two more points should be stressed, that is, they repeated the teacher's commands as a device to better direct their movements. This kind of self-instruction gave them more confidence. 1) At first, when they were still uncertain about the movements requested they imitated not only their teachers, but also their peers. 2) then, after acquiring a certain flexibility, they stopped a) imitation, b) looking around and c) self-instruction and did the exercises showing a certain automatism, due to unconscious memory. With a new exercise they went back to repeat the same phases (imitation and self-confidence) so, to regain confidence.

2) Neurological system

Before going into the specific issue related to physical education, it is necessary to give a description of the brain. These notions, enriched with pictures, can be valued only as a brief illustration, and not as a scientific study; it should be intended only to visualize the exact location of each area as well as to clarify their functions. Knowledge and understanding in general, but in this specific case, regarding the function of the brain, in both good and bad conditions, provide a benefit to understand how it works and what it needs in order to both maintain a perfect condition or avoid damage. By looking at these description we, also, realize that memory as well as movements are included in numerous areas of the brain. For this reason, there is an exchange of functions among the areas of the brain, one supplying the other if some problems impede its functioning.

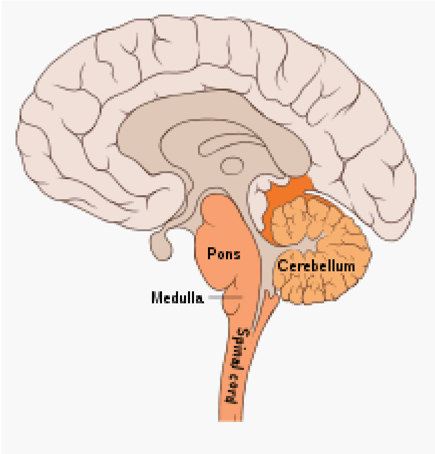


The Hippocampus

The hippocampus is a structure in the brain associated with various memory functions. It is part of the limbic system, and lies next to the medial temporal lobe. It is made up of two structures, the **Ammon's Horn**, and the Dentate gyrus, each containing different types of cells. The hippocampus contains cognitive maps. The hippocampus' right side is more oriented towards responding to spatial aspects, whereas the left side is associated with other context information. Also, there is evidence that experience in building extensive mental maps, such as driving a city taxi for a long time (since this requires considerable memorization of routes), can increase the volume of one's hippocampus. The hippocampus is important for encoding complex memories and memory consolidation, which is the process by which memories are converted from short to long term memory.[12]

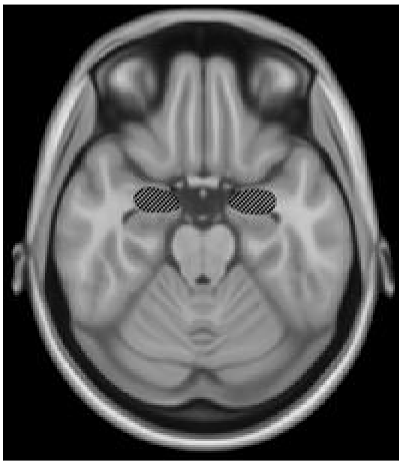
[12] Warrington, E., & Weiskrantz, L. (1973). An analysis of short-term and long-term memory defects in man, in J.A. Deutsch, ed. *The Physiological Basis of Memory*. New York, Academic Press.

The cerebellum



The cerebellum is a structure located at the rear of the brain, near the spinal cord. It plays a role in the learning of procedural memory, and motor learning, such as skills requiring co-ordination and fine motor control. An example of a skill requiring procedural memory would be playing a musical instrument, or driving a car or riding a bike.[13] Since the cerebellum is more generally involved in motor learning, its damage generates movement problems. It co-ordinates timing and accuracy of movements

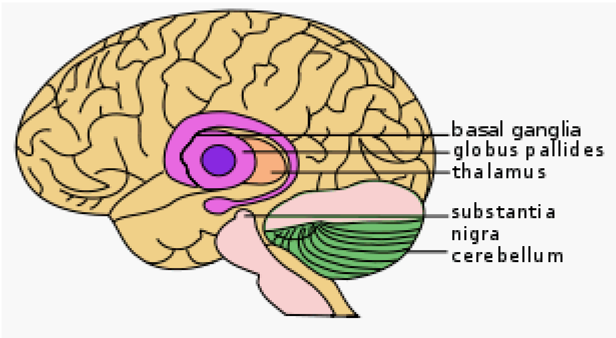
Amigdalae



The two amygdalae are located above the hippocampus in the medial temporal lobes. The amygdalae are associated with both emotional learning and memory, as they respond strongly to emotional stimuli, especially fear. These neurons assist in encoding emotional memories at a deeper level into memory, so avoiding to forget bad events.

[13] Mishkin, M.and Appenzeller, T., The anatomy of memory, in *Scientific American,* 1987, **256** (6): 80–89.

The basal ganglia



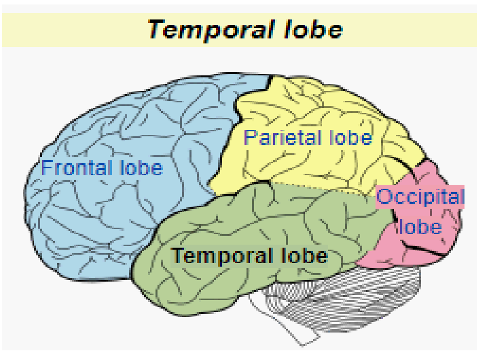
The basal gangliae are a group of nuclei which are located in the medial temporal lobe, above the thalamus and connected to the cerebral cortex. Specifically, the basal ganglia includes the subthalamic nucleus, substantia nigra, the globus pallidus, the ventral striatum and the dorsal striatum, which consists of the putamen and the caudate nucleus. The basic functions of these nuclei deal with cognition, learning, and motor control activities. The basal gangliea are also associated with learning, memory, and unconscious memory processes, such as motor skills and implicit memory.[14]

The Cerebral cortex

The **cerebral cortex** is the largest region of the cerebrum in the brain and plays an important role in memory, attention, perception, cognition, awareness, thought, language and consciousness.

The cerebral cortex is the most anterior (rostral) brain region and consists of an outer zone of neural tissue called gray matter, which contains neuronal cell bodies. It is also divided into left and right cerebral hemispheres by the longitudinal fissure, but the two hemispheres are joined at the midline by the corpus callosum.[15]

The lobes



[14] Implicit memory (muscle memory) is sometimes referred to as unconscious memory or automatic memory. Implicit memory uses past experiences to remember things without thinking about them. The performance of implicit memory is enabled by previous experiences, no matter how long ago those experiences occurred. Cf. McGaugh, JL, The Amygdala modulates the consolidation of memories of emotionally arousing experiences, in *Annual Review of Neuroscience,* 2004, **27** (1): 1–28.

[15] Kandel, Eric R.; Schwartz, James H.; Jessell, Thomas M. (2000). *Principles of Neural Science* (Fourth ed.). United State of America: McGraw-Hill: 324.

The frontal lobes

The frontal lobe is part of the brain's cerebral cortex. Individually, the paired lobes are known as the left and right frontal cortex. As the name implies, the frontal lobe is located near the front of the head, under the frontal skull bones and near the forehead. It was the last region of the brain to evolve, making it a relatively new addition to the structure. The frontal lobes are located at the front of each cerebral hemisphere and positioned anterior to the parietal lobes. It is separated from the parietal lobe by the primary motor cortex, which controls voluntary movements of specific body parts associated with the precentral gyrus. The cortex here serves our ability to plan the day, organize work, type a letter, pay attention to details and control the movements of your arms and legs. It is also involved in memory, when controlling the coordination of information.[16]

Temporal lobe

The temporal lobes are a region of the cerebral cortex that is located beneath the Sylvian fissure on both the left and right hemispheres of the brain. Lobes in this cortex are more closely associated with memory and in particular autobiographical and recognition memory.[17]

Parietal Lobe

The parietal lobe is located directly behind the central sulcus, superior to the occipital lobe and posterior to the frontal lobe, visually at the top of the back of the head. The parietal lobe has many functions and duties in the brain and its main functioning can be divided down into two main areas: (1) sensation and perception (2) constructing a spatial coordinate system to represent the world around us. The parietal lobe helps us to mediate attention when necessary and provides spatial awareness and navigational skills. Also, it integrates all of our sensory information (touch, sight, pain etc.) to form a single perception.

Occipital lobe

The occipital lobe is the smallest of all four lobes in the human cerebral cortex and located in the rearmost part of the skull and considered to be part of the forebrain. The occipital lobe is above the cerebellum and is situated posterior to the Parieto-occipital sulcus, or parieto-occipital sulcus. The

[16] Kuypers H., *Anatomy of the descending pathways* (V. Brooks ed.), The Nervous System, handbook of Physiology, vol. 2, Baltimore, Williams and Wilkins, 1981.

[17] Conway, M. A., Pleydell Pearce, C. W., The construction of autobiographical memories in the self memory system, in *Psychological Review*. **107** (2), 2000: 261–288.

main function of the occipital lobe is that of vision.

4) Neuroplasticity and Irisin – The Exercise Hormone.

Neuroplasticity and irisin are, in my opinion, the two main components acting as important stimuli during physical movement. They provoke an increasing in the functions of the brain, thus improving cognition and behavior, as well as a prevention of obesity and diabetes, which are a serious risk in our society, being a public health crisis that affects most of the Western civilization.

> The ongoing global epidemic of chronic non-communicable diseases (NCDs) is related to changes in lifestyle, including low physical activity (PA) levels. Physical inactivity is a major public health challenge and has been defined as the fourth leading cause of dead worldwide. The health benefits of regular PA are well established, and elimination of physical inactivity would remove between 6 and 10% of NCDs and increase life expectancy. Moreover, cardiorespiratory fitness (CRF) is a strong predictor of health and longevity. There are large individual differences in CRF among adults who are sedentary and who have a history of not engaging in regular exercise.[18]

a) Irisin

The good news, for the lazy people, is that even a small amount of moderate exercise stimulates the production of irisin. Thus, aerobic is not 'a bad word,' since it can be used as one prefers, from walking to more strenuous exercises. In brief, the more intense your exercise is, the more irisin you will produce. However, we must add that chronic exercise does not increase irisin levels well, rather short period of intense activity increase it significantly. Neuroplasticity and irisin are also fundamental issues for shaping our mind in the right direction in order to prevent either many of the diseases belonging to senescence or traumatic strokes due to accidents. Recent studies emphasize that physical activity is one of the most relevant enhancer to establish a real balance between our physiological and psychological ways of life. From the physiological point of view, PE is associated to the natural production of irisin – a fat burning hormone that is released during moderate aerobic endurance activity, when the cardiorespiratory system is engaged and muscles are exerted. This hormone regulates obesity and diabetes, while from the psychological side PE has a decisive role in enhancing a positive attitude towards both life and people. Irisin developed after movements regulates fat tissue and blood sugar by turning white fat cells into brown fat cells, which have the capacity to continue to burn fat after finishing exercises. This hormone is produced in muscles and fat tissue, and it is also synthesized in the brain (hypothalamus along with neuropeptide – chemical signals in the brain «small protein-like molecules» used by neurons to communicate with each other), cerebrospinal fluid, heart muscle, along with peripheral tissues, including salivary glands, kidney and liver. Among the many characteristics of irisin we have to say that it is also an anti-inflammatory and an anti-oxidant, thus lowering total cholesterol, chronic kidney disease, coronary artery disease, etc.. Among many other advantages it increases cognitive and brain function as well as motivation. Physical exercises provide our mind with a sense of freedom and satisfaction for many reasons. They enlarge our mind and our body by giving us a perception of satisfaction and power; feelings that make us happy, and when people feel happy they show a positive attitude towards other people, too. Physical exercises give our bodily shape balanced proportions, thus stimulating to eat healthy food. All these details are very important, because when we feel satisfied with ourselves we face problems with an open disposition and with a cognitive flexibility. Fagundo et al in the article Modulation of Irisin and Physical Activity on Executive Functions in Obesity and Morbid Obesity delineate the many positive effects of PA, even curing deficits in attention, memory

[18] He Zihong et al., Cardiorespiratory Fitness Response to Regular Exercise, in Spiegelman (eds.) 2017.

and executive functions. Of course, mice are the most common test subjects used by scientists to experiment their findings.[19]

> Recent neuroimaging studies also suggest that a combination of omega-3fatty acids, aerobic exercise and cognitive stimulation prevents a decline in the gray matter volume of the frontal, parietal and cingulated cortex in patients with mild cognitive impairment. Particularly interesting are those studies suggesting that physical activity, a balanced diet, cognitive stimulation or the management of conditions such as diabetes and obesity are preventive factors in Alzheimer's diseases.[20]

b) Neuroplasticity

> Neural plasticity is the ability of the nervous system to change its function. It is a property of the nervous system and its presence only becomes evident when activated (turned on). Lack of sensory signals and inactivity such as lack of muscle usage are the most common factors that can induce plastic changes. … Activation of neural plasticity is necessary for normal development of the brain at birth. Sensory signals help guide the development of the brain during early childhood and neural plasticity provides a 'midcourse correction' of what was laid down before birth. … The changes that are induced through activation of neural plasticity involve the way connections between more cells (synapses) work. The efficacy of synapses can change, new synapses can be formed and synapses can be eliminated. … Throughout life, activation of neural plasticity can reorganize the nervous system by opening new routes for information. Activation of neural plasticity can enhance or suppress reflexes and change which parts of the brain are used for different tasks. … Extended use of senses improves functions and extended use of muscles or muscle groups can improve manual skills. … Activation of neural plasticity is also necessary for further maturation of the brain. After the correction that occur immediately after birth have been completed, the way the brain is wired can still change because it is plastic. Changes occur when children are exposed to an 'enriched sensory environment', and sensory signals help to develop the nervous system to the best possible usage.[21]

The above quotation synthesizes the main notion about the relationship between the importance of offering as many stimuli as possible to our brain, especially during the first years of life, because, in so doing, we give infants and young children the chance to develop a series of important notions that will regulate their future life forever. Our program of physical exercise, through music and instructions, has the aim to stimulate, through the sensory system, the plasticity of the brain and cognition while constructing a well balanced psychological and social attitude. Teaching PE to young children, who are still trying to know the structure of their body and how to use it, so, to control and organize their movements according to a project, can be very effective : "Control of movement is highly adaptable to changing demands and that is a result of neural plasticity being turned on. … training can increase motor skills. … We may call this learning but it is in fact a matter of neural plasticity because activation of the skills does not involve conscious recall as does memorization of telephone numbers, etc."[22]

---

[19] Zhang J. Et al., Exercise-induced irisin in bone and systemic irisin administration reveal new regulatory mechanism of bone metabolism, in *Bone Research*, 2017, 5:56; cfr. *American Journal of Physiology – Endocrinology and Metabolism*, September, 2016; cfr. Boström P. et al., A PGC1-α – dependent myokine that drives brown-fat-like development of white fat and thermogenesis, in *Nature*, 481 26 January 2012: 463-468; Timmons J. A. et al. Is irisina human exercise gene? In *Nature*, 488, 30 August 2012: 463-468.

[20] Fagundo A. B. and al. Modulation of Irisin and Physical Activity on Executive Functions in Obesity and Morbid Obesity in *Scientific Report*, 2016, August 1: 1-6.

[21] Møller, 2009: 27, 68

[22] Møller, 2009: 65.

As we can realize from the above description of the brain, there is not a strict relation between each area and its functions, as it was attested in the past. Rather, there is a kind of shifting, in which memory, because of its different types (**conscious** – *declarative* (memory of facts) and *episodic* (memory for life events) –, and **unconscious** – *procedural* (memory for skills), and, because it involves many different areas of the brain, plays a fundamental role. Physical movements, in order to complete exercises, seem to require all kinds of memory; thus, taking advantages of this opportunity. Moreover, there are similarities between neural plasticity and memory, in the sense that once a skill has been learned through activation of neural plasticity, the skill will be memorized even if we do not practice it for some time: "The skill remains for a long time, often forever. Learning to ride a bicycle is common example of learning motor skill that can last a lifetime"(Møller). This is called motor memory, and we will discuss about it in a following paragraph.

> Neural plasticity has many similarities with memory but there are also differences. Both memory and plasticity are based on changes in the brain that occur because of experience and practice. The changes in the function of the brain involved in memory and learning entail modification in both synaptic strength and in the organization of neural networks. Memory may be defined as something that can be consciously recalled, whereas neural plasticity involves changes in the function of the spinal cord and the brain that occur unconsciously and which cannot be recalled willfully. … Learning and memory make it possible to recall both external (sensory) and internal events (thoughts, dreams). … Learning leaves permanent traces in the brain consisting of neural circuits that are created in different places in the brain every time something is learned. These neural circuits may stay active for a life time. However, it may be difficult to retrieve the information. Neural plasticity involves the ability to change the function and the organization of the nervous system in a similar way as learning but the plasticity changes cannot be directly recalled as a memory.[23]

In the past, researches showed that the many areas of the brain were each isolated from one another, and strictly deputed to a specific skill. Even though in 1890 William James, in his book *The Principles of Psychology*, talks about a certain plasticity of the brain (the capacity to produce new 'wires' or neural pathways), his theory has been ignored for many years. And also ignored remained the evidence of the brain changes as attested by Karl Lashley in 1920s with his experiments in the neural pathways of rhesus monkey. The theory was that changes in the brain could take place only during the critical period (infancy and childhood). After that age the brain structure remained unchanged. In brief, the connections in our brain remained fixed and then they simply faded during the old age.

> It was earlier believed that neural plasticity could not be activated after a certain age, but it is now known that neural plasticity can be induced also after childhood, although to a lesser degree. … For many years it was assumed that plastic changes could only occur in young children and that only the developing nervous system could be changed (was plastic). However, many recent studies have confirmed that the adult brain is plastic as well. It is easier to activate neural plasticity in children than in adults, and the changes in function that can be achieved through activation of neural plasticity are more extensive in children.[24]

As said before, only by the 1960s, researchers started to believe, through the exploration of people regaining skills after massive brain strokes, that the brain was really malleable. The first studies on neuroplasticity belong to the changes of children's' brain under the effect of learning more than one language. It seems that the left inferior parietal cortex is larger in bilingual brains than in monolingual subjects. Nowadays, new researches attest that brain areas are not so fixed,

---

[23] Møller, 2009: 28.

[24] Møller, *The Malleable Brain*, Nova Biomedical Books, New York, 2009: 48-58.

rather they collaborate with one another, as we can see for skills concerning memory, which belongs to many areas, and for second language (writing and reading), which are regulated by the right hemisphere, too. In the past, language was believed to be controlled by the left hemisphere only. Nowadays, because the brain also possesses many neural pathways that can replicate functions, once some damage occurs to others, it is possible to recover the loss abilities. Cognitive functions are processed by a network (connectome) of interconnected brain areas. Furthermore, the new advanced technology (neuroimaging) has given researchers the possibility to examine in detail the many processes the brain goes through, especially when people recover most of their functions after brain damages. In fact, the brain possesses the capacity to reorganize its pathways by creating new connections and, remarkably, it may even originate new neurons. In other words, while in the past, it was believed that the approximately 86 billion neurons we have, stopped increasing shortly after birth, today scientists attest the great capacity of the brain to renew its shape. This is possible because the brain processes sensory and motor signals in parallel. In sum, the brain is not a fixed organ, rather it evolves for better or worse, changing its shape, under different conditions. When a damage occurs and cancels the performance of some abilities, the flexibility of the brain permits, under a proper treatment, to increase synaptogenesis (the chance to increase the number of synapses), and to recover the functions related to the damaged connections through the undamaged connections. We have to mark that, even new experiences change the shape of the brain by reinforcing its role any time it receives new inputs. Under the notion of experience, we have to include either external or psychological and physiological events, which, while influencing the development of cognitive growth, consequently, enrich behavior in order to reach the new goals.

> Our brain is constantly changing during lifetime. During fetal development structural changes are dominant, such as neurogenesis and migration of neurons, while in adult brain the dominant type of neuroplasticity is functional, allowing the brain to constantly adapt to environment and injury. The greatest challenge for neurorehabilitation in the future is finding and defining major and minor neural pathways, and then aim to support neuroplasticity of compensatory neural circuits.[25]

Another relevant point discussed by Kolb, Gibb and Robinson is the one related to brain changes during pre-natal experience, and how these changes can affect the future structure of the brain as well as the subject's behavior. In addition, these studies on animals of different ages (juveniles, adulthood and senescence) and on "the offspring rat housed in a complex environment during the term of her pregnancy" showed that the consequences of this stimulating environment produce a considerable change in the brain even in adulthood. These researches are, above all, important to cure future impairment caused by accidental events or by additives.

> … we then asked whether prenatal experience might also change the structure of the brain months later in adulthood. Indeed, it does. … Although we do not know how prenatal experiences alter the brain, it seems likely that some chemical response by the mother, be it hormonal or otherwise, can cross the placental berrier and alter the genetic signals in the developing brain. … What was surprising, however, what that prenatal experience, such as housing the pregnant mother in a complex environment, could affect how the brain responded to an injury that it would not receive until after birth. In other words, prenatal experience altered the brain's response to injury later in life. This type of study has profound implications for preemptive treatments of children at risk for a variety of neurological disorders.[26]

---

25 Demarin V., Morovic S. and Béné R., Neuroplasticity, in *Periodicum*, vol. 116, n. 2, 2014: 209-211.

26 Kolb B., Gibb R., and Robinson T., Brain Plasticity and Behaviour, in *Current Directions in Psychological* Science, vol. 12 n. 1 February 2003:1; cfr. Kolb and Gibb, Brain Plasticity and Behaviour in the Developing Brain, in *Journal Canadian Acad Child Adolescence Psychiatry*, vol. 20 (4), Nov. 2011: 265-276.

Jerzy Konorsky (1903-1973 Poland, coined the term brain plasticity and developed Ivan Pavlov's theory) found that active neurons while changing, produce a transitory or an enduring development (a phone number we soon forget or a phone number we memorize). Donald Hebbs, in 1949, proposed that the neurons change, because stimulation activates new synapses when two neurons are active; under these conditions, it is possible to establish a connection between them.[27] So, plasticity is a property coming from the synapses. In order to value the different phases the brain goes through, Hebbs describes the case of a woman whose brain, during her life, performed transitory as well as enduring changes. This woman (Donna), during her childhood, like all human beings, had at first to learn a language, to walk, to read, to dance, etc.. Then, as she grew up, she had to face other kinds of experiences that inevitably modified the structure of her brain. She stopped dancing for 10 years, but when she started again, because her brain had retained much of this skill, it was easy for her to relearn her ability to dance. It was more difficult to relearn how to walk, to talk, and to dance after an accident happened to her, but she regained the lost abilities due to the brain plasticity, which, even going through different phases, gave her the opportunity to live quite a satisfactory life. Hebbs, in order to stress on the importance of a stimulating environment, and its positive results in changing the shape of the brain, because of the emergence of new synapses, brought home several laboratory rats. The experiment wanted to compare the brain of the two groups of rats; the ones living in a more stimulating area (his home) and those ones living in a cold laboratory. The obvious results showed that the richer experience improved rats' performance, and established that, by looking at the dendrite, more synapses had emerged.[28]

> We placed animals in complex environments either as juveniles, in adulthood, or in senescence. (Kolb, Gibb, & Gorny, 2003). It was our expectations that there would be quantitative differences in the effects of experience on synaptic organization, but to our surprise, we also found *qualitative* differences. Thus, like many investigators before us, we found that the length of dendrites and the density of synapses were increased in neurons in the motor and sensory cortical regions in adult and aged animals housed in a complex environment (relative to a standard lab cage). In contrast, animals placed in the same environment as juveniles showed an increase in dendritic length but a decrease in spine density.[29]

[27] Sejnowski, T. J. The Book of Hebb, in *Neuron*, vol. 24, 1999: 773-776.

[28] **Dendrites**, also **dendrons**, are branched protoplasmic extensions of a nerve cell that propagate the electrochemical stimulation received from other neural cells to the cell body, or soma, of the neuron from which the dendrites project. Electrical stimulation is transmitted onto dendrites by upstream neurons (usually their axons) via synapses which are located at various points throughout the dendritic tree. Dendrites play a critical role in integrating these synaptic inputs and in determining the extent to which action potentials are produced by the neuron. Cf. Hebb D., *Organization of Behavior: A Neuropsychological Theory*, Wiley, New York, 1949; Pascual-Leone A., Freitas C., Oberman L., Horvath J. C., Halko M. et al., Characterizing brain cortical plasticity and network dynamics across the age-span in health and disease with TMS-EEg and TMS-fMRI, in *Brain Topography*, 24: 302-315; Gerstner W., Hebbian Learning and Plasticity, in *From Neuron to Cognition via Computational Neuroscience* (M. arbib and J. Bonaiuto edited by), MIT Press Cambridge, 2011, Chapter 9.

[29] Kolb B., Gibb R. and Robinson T. E., Brain Plasticity and Behavior, in *Current Directions in Psychological Science*, vol. 12, n. 1, February 2003.

4) The Nun Study

The Nun Study,[30] conducted by Hebb, is crucial for establishing that the more experience we receive the more synapses emerge, and, consequently, life acquires a healthier condition.[31] Thus, I will consider the very new theories which describe how the brain changes its functions in order to adapt to the new situations arisen from new learning. Any time we add new knowledge, the level of connections between neurons increases, altering the brain structure; the areas in our brain that deal with this type of skill also grow. Learning should never stop during our life, because new knowledge renew our brain by giving birth to new synapses which reinforce our memory and slow down the damage related to age. In fact, the brain never stops changing if reinforced by novel experiences. It has been attested, after specialized neurological experiments in various fields, that the more you exercise your memory, the longer you live, because you train your brain by using either spatial, linguistic or academic information. By comparing London taxi drivers to London bus drivers, it has resulted that the first drivers have a larger hippocampus (the posterior region of the brain) than the second group, just because this region of the brain has been trained in acquiring and using complex spatial information, while the bus drivers do not exercise much their brain due to the same route they follow every day. Bilingual people also show changes in the left inferior parietal cortex, which is larger compared to monolingual subjects. Musicians, compared to non-musicians show that the volume of the gray matter (cortex) is higher. Dragansky et al. have attested that extensive learning induces some plastic changes in the brain. They have analyzed some German medical students 3 months before their exams and right after the exam; then they compared their brains to those of other students who were not preparing any exams at that time. The students who prepared for exams showed changes in both the parietal cortex and the posterior hippocampus – regions involved in memory retrieval and learning; thus, attesting that adding new knowledge induces changes in the brain.[32]

We have to consider that changes in the physiological structure of the brain underlie behavioral changes, too. as Kolb affirms "it is the brain that controls behavior." Kolb, in order to consider the properties of the brain takes into account "some assumptions and biases that underlie thinking about plasticity."

1) *Behavioral states, including mind states, correspond to brain states.* … I assume that it is the brain that thinks and controls behavior, and try to show that an understanding of plasticity will be enlightening with respect to how it does these tricks. …
2) *The structural properties of the brain are important in understanding its function.* … Rather, I assume not only that changes in structure underlie behavioral change but also that it is possible to identify and potentially influence those changes. …
3) *Plasticity is a property of the synapse.* … The idea that neurons are somehow changed with use is important, for it means that one could look at the neuron and try to identify the changes. The question is, however, where do you look? A Canadian psychologist, Donald Hebb, proposed in that the logical place to look is at the synapse. He suggested that when synapses are active, they change *if the conditions are right*. For Hebb, the most important

[30] The nun study is a longitudinal study of aging and Alzheimer's disease. It followed 678 sisters of the School Sisters of Notre Dame living in Mankato, Minnesota. The goal of the study is to identify the risk factors for Alzheimer's other brain diseases. Some of the results of the study confirm the commonsense notions that healthy lifestyle and active and stimulating intellectual life can help us stay healthy and independent later in life. But the most surprising finding is that certain traits in early 20s can help predict whether someone will have Alzheimer's disease 60 years later. Iacono D., et al. The Nun Study – Clinically silent AD, neuronal hypertrophy, and linguistic skills in early life, *Nature* vol. 427, January 2004: 311-312.

[31] Danner D., Snowdon D. A., et al., Positive Emotions in Early Life and Longevity : Findings from the Nun Study, in *Journal of Personality and Social Psychology*, vol. 80, n. 5, 2001: 804-813.

[32] Cf. Draganski B., Gaser C., Busch V., Schuierer G.,Bogdah U. & May A., Neuroplasticity: Changes in grey matter induced by training, in *Nature*, vol.427, January 22nd, 2004: 311-312; Zarrelli N. The neurologists who fought Alzheimer's by studying nuns' brain, March 24th 2016.

condition was that two neurons had to be coincidentally active and if so, then the connection between them was strengthened. Hebb's addition was important, for it (a) specified the conditions under which plasticity would occur and (b) pointed to a role of both the pre- and postsynaptic side of a connection in plasticity. This latter conclusion means that plasticity can be measured either pre- or postsynaptically. It also follows from Hebb's proposals that during development, learning, recovery from injury, and aging, there are changes at the synapse that allow the brain to be functionally plastic.

4) *Behavioral plasticity results from summation of plasticity of individual neurons. …*
5) *Specific mechanisms of plasticity are likely to underlie more than one form of behavioural change. …*
6) *The cortex is the most interesting candidate for neural plasticity. …*[33]

In a healthy brain several factors might enhance neural plasticity. These are hormones, trophic factors, neuro-modulators, aging, injury, environment, the last emphasizing experience, which can be internal and external. Plasticity of the brain influences behavior, too. This has been demonstrated after analyzing our behavior after an injury that have limited our capacities. The brain changes in order to recover the original behavior. In fact, if we feel a muscular or a nerve pain that impedes our arm to move as usually, our posture changes in order to reach the desired object. The brain plasticity is responsible for these changes. Kolb presents his personal experience to clarify this mechanism.

> One morning in January 1986, I awoke to discover that I was unable to see anything in the left half of visual space. … Within a few hours the left visual field began to change. The lower quadrant of my visual world would begin to return, and within a few more hours my vision appeared to be fairly normal in the lower field. The upper quadrant was very slow to change, however, and a computed tomography (CT) scan revealed damage to the lower bank of the right calcarine fissure. … I had lost pattern vision in one-fourth of the foveal representation … . There were changes in my vision over the next weeks and months that could be described as recovery. … I have compensated for the loss. I am able to read not because I can see in the left upper fovea again but because I do not try to use this region to read with. Rather, I have learned to fixate so that parts of the words that once fell in the left upper fovea now fall in the lower field. I am told by observers that I do this by tilting my head to one side, although I am not conscious of doing this.[34]

Møller, in order to explain the plasticity of the brain, and how it adapts to new situations takes as an example "the cells of the hearing nervous system normally tuned to different frequencies and anatomically arranged according to the frequency of the sounds that reach the ear. … The normal 'tonotopic organization' of nerve cells evolves because of the ability of the cochlea to separate sounds according to their frequency. This causes sounds of different frequencies to activate nerve cells in the hearing pathways according to the frequency of the sounds. Through exposure to sounds, nervecells become 'tagged' and they become anatomically organized according to the frequencies to which they respond best. This is what we call tonotopic organization. This form of neural plasticity is turned on by signals from the ear that is elicited when sound from the entire audible frequency range of hearing activate the ear. This means that the tonotopic organization is directed by sound but requires many different kinds of sound. … the development of normal synaptic activity requires stimulation of the sensory system.[35]

In brief, experience from exposure to sensory stimulation is a necessary expedient for a normal development of our senses.

---

[33] Kolb B., 1995: 8-10.
[34] Kelb, 1995: 40-41.
[35] Møller, 2009: 68-69.

5) Physical exercises and memory

In the light of these discussions, and also considering that for children, it is easier to acquire new knowledge, which inevitably enlarges their cognition by giving them new values and new aims to achieve and to follow, I have decided to stimulate their brain and their behavior by offering them the marvelous experience to control, to know, to experiment their body through a series of physical exercises, which, at last, balanced and improved their cognitive, mental and physiological capabilities. Their brain will also model differently after a series of new experiences, because even though under the influence of the new studies about the plasticity of the brain, a plasticity occurring at any age under a certain stimulation, we cannot negate that experiences early in life have a more positive effect on behavior than similar experiences happened later in life. In fact, movement, since it implies: a) attention; b) encoding; c) storage of information, and d) retrieval, seems one of the most important activities to be trained even in very young children. Physical exercise enhances the plasticity of the brain, and by giving access to new information about the body (how it works, how it grows, how it functions, how it modifies), about the notions related to time and space, about relationship, about punctuality, about having respect for other people, provides the basic notions to face life adequately. The more exercise you do, the more memory you can bank, and the easier it is to make deposits. This is possible because, new scientific researches attested that the new nuclei added during a training period will never be lost. This means that resistance training induces permanent physiological changes in muscle fibers and in the brain.[36]

It seems necessary to stimulate not only children but the hole staff of the school about the importance of physical education combined with different areas of knowledge. During my research, the teachers of the school examined were very cooperative, even organizing, during the school year, theoretical seminars in which I had the chance to explain to both pupils and parents the main aim of physical exercises, but above all to link gymnastics to the other subjects of the school curriculum. This meta analysis wants to evaluate my results by combining and contrasting them with other studies referring to the importance of movements for everybody, but in particular for teenagers. In our society, nowadays, PI is growing in importance, so, it seems necessary to focus on this subject also within the school curriculum.

An active life stimulates children not only on the physical side, but on the cognitive level, too (Etnier and Sibley, 2003). It has been proved that when children have enough exercises their mind becomes more receptive, and even their curiosity seems to improve, considering that curiosity is the driving force of learning.

The connection between mind and body pushed Kramer researches into the field of movement, so to establish that "Across the board, exercise increases brain function, memory retention and other key areas of cognition up to 20%."[37]

> Physical education is a field that advocates a holistic approach to human development. This approach emphasizes that the mind and the body are one entity, and that anything that happens to one will affect the other. Physical educators therefore believe that the "whole child" comes to school to be educated and that this requires both mental and physical training. The relationship between physical activity and mental functioning is of particular interest in the school system because such a large portion of the school day is spent working on the cognitive domain. … It seems that the need to justify exercise and PE programs in the schools has returned. … In contrast to this view (School administrators often cite budget restrictions and the need to spend more time

---

[36] Cf. Brashers-Krug, T; Shadmehr, R.; Bizzi, E., 1996. Consolidation in human motor memory, in *Nature. **382**: 252–255;.* Atwell, P.; Cooke, S.; Yeo, C., 2002, Cerebellar function in consolidation of motor memory, in *Neuron. **34**: 1011–20;* Boyden, E.; Katoh, A.; Raymond, J., 2004 Cerebellum-dependent learning: the role of multiple plasticity mechanisms, in *Annu. Rev. Neurosci.* **27**: 581–609.

[37] Kramer A., Aerobic Exercise Training Increases brain Volume in Aging Humans, in *Journal of Gerontology: Medical Science*, 61(11): 1166-70, December 2006.

on "academic" subject as the primary reasons for cutting PE programs. … In contrast to this view that "non-academic" classes should be cut so more time can be spent in the classroom, there are many educators who believe that physical activity and PE actually have a positive impact on concentration, learning and academic success.[38]

There is ample evidence that participating in moderate-to-vigorous physical activity (MVPA) can lead to a variety of benefits for children and adolescents. Compared with their inactive counterparts, youth who are sufficiently active enjoy better physical health (U.S. Department of Health and Human Services, 2000), report more positive physical self-concept and global self-esteem, perceive a better quality of life, and achieve higher academic results. Unfortunately, the physical activity (PA) levels of many children and adolescents are currently insufficient to promote these benefits. In response to this evidence, the importance of schools in PA promotion has been highlighted, and the central role of physical education (PE) programs in this effort has been emphasized.[39]

Booth Frank and Chakravarthy Manu in their article also emphasize the importance of movement especially for sedentary people, and suggest at least 30 minutes per day of physical activity in order to prevent coronary heart disease, type 2 diabetes, obesity and obesity-related disorders in the aging population.[40]

Physical inactivity increases the risk of many chronic disorders. Numerous studies have convincingly demonstrated that undertaking and maintaining moderate levels of physical activity (eg, brisk walking 3 hours a week) greatly reduces the incidence of developing many chronic health conditions, most notably type 2 diabetes mellitus, obesity, cardiovascular disease, and many types of cancers. However, the underlying mechanistic details of how physical activity confers such protective effects are not well understood and consequently constitute an active area of research. Although changing an individual's ingrained behavior is commonly perceived to be difficult, encouraging evidence suggests that intensive and repeated counseling by health care professionals can cause patients to become more physically active. Therefore, counseling patients to undertake physical activity to prevent chronic health conditions becomes a primary prevention modality. This article summarizes the vast epidemiologic and biochemical evidence supporting the many beneficial health implications of undertaking moderate physical activity and provides a rationale for incorporating physical activity counseling as part of routine practice in the primary care setting.[41].

Booth and Lees by comparing the changing living conditions between the past (the beginning of the 1900s) and the present days, establishing that "sedentary individuals were likely rare in 1900, a time before automobiles, industrial assembly lines with machines, computers and convenience technologies" attest that "physically inactive lifestyles are an *actual* contributing cause of Alzheimer's disease, breast cancer, colon cancer, coronary artery disease, obesity, osteoporosis, sarcopenia, type 2 diabetes, and others. Therefore physical inactivity and chronic disease are not separate disciplines – they are inevitably linked, and this point seems to have been

---

[38] Sibley B. A. and Etnier J. L., The Relationship Between Physical Activity and Cognition in Children: A Meta-Analysis, in *Pediatric Exercise Science*, 15, 2003: 243-256; cfr. Sallis F. J. et al . Effects of health-related Physical Education on Academic Achievement: Project SPARK, in *Research Quarterly for exercise and sport*, 70 (2), July 1999: 127-134.
[39] Lonsdale, C., Rosenkranz R.R. et al. A systematic review and meta-analysis of interventions designed to increase moderate-to-vigorous physical activity in school physical education lessons, in *Preventive Medicine*, 56, 2013: 152-161.
[40] Booth F. W. and Chakravarthy M. V., Cost and Consequences of Sedentary Living: New Battleground for an Old Enemy, in *ERIC*, Number: ED470690, 2002 March: 10.
[41] Chakravarthy M. V., Joyner J. M. and Booth F. W., An Obligation for Primary Care Physicians to Prescribe Physical Activity to Sedentary Patience to Reduce the Risk of Chronic Health Conditions, in *Mayo Clin Proceedings*, Vol. 77, February 2002: 165-173.

underemphasized."[42] As a consequence, if children at kinderkarten are stimulated to practice regularly physical exercises that enable their body to move imitating certain positions, they will inevitably acquire the skill of taking care of their body not only as an external object, but, moreover, as an internal structure which needs good food both for the brain and for healthy future life. They should have at least 30 minutes a day of physical activities, employing not only formal gymnastics but moreover games, so the whole body as well as the brain are involved. In doing so, they develop enough strength to use hands, fingers, arms, legs in order to coordinate physical movements with eyes movements. This exercise will drive them to pursue their aim according to the group they belong to. They will learn important skills while their brain either controls or commands their body. Sallis et al. in their researches established that additional time dedicated to physical education as part of academic education provided opportunities for all children to exhibit a more positive attitude towards school in general, and towards the learning of school subjects in particular: "the health-related physical education program did not interfere with academic achievement. Health-related physical education may have favourable effects on students' academic achievement."[43] While learning how their body works and what their body needs, children become conscious about how to maintain a healthy body. As the name – physical education – suggests, children are educated to exploit their potential, so to be able to command their body. Furthermore, while practicing physical exercises, children come across the notion of space and time in relation to their body. In fact, they have to measure the space in which their body will move, and they have also to follow a precise time according to the rhythm of the music, which will direct their movements. This is a very important stage for young children who learn how to control their body while familiarizing with it. New recent trends associate, even for very young children, gymnastic with nutrition, thus stimulating them to accept a diet rich in fruit and vegetables (*Health United States*, 2005). In brief, physical activity, by emphasizing locomotor, non-locomotor and manipulative skills, becomes an important venue for the social, psychological and emotional developments of children (Lonsdale et al. 2013). They learn how to move their body, how to coordinate their movements in relation to others, but most importantly, how to follow the teacher's instructions in connection with the group.

> All children should be set tasks that are appropriate to their physical, cognitive and social development, which will enable them to engage in active learning time. … teachers should ensure that they are familiar with the STEP framework (space, task, equipment and people) for effective differentiation of activities.[44]

6) Motor Memory or Muscle Memory

Memory, as previously seen, belongs to different areas of the brain, because the various types of memory, even though they have their own particular mode of operation, cooperate in the process of memorization. In sum, we have: 1) sensory; 2) short-term, and 3) long-term memory. The sensory memory is the shortest-term memory and implies the senses of sight, hearing, smell and taste. Only the smell memory may persist for a long time even without reinforcing the sensation linked to a particular odor. The short-term memory can, at the same time, remember and process the information, which will soon disappear, unless we make a conscious effort to retain it. The long-term memory stores information for a long time, and it is divided into: 1) spatial memory, 2)

[42] Booth F. W., Lees S. J., Physically Active Subjects Should Be the Control Group, in *Journal of the American College of Sports Medicine*, 2006.
[43] Sallis JF., McKenzie TL et al., Effects of health-related physical education on academic achievement: project SPARK, in *Res Q Exercise Sport*, Jun., 70 (2), 1999: 127-34.
[44] Powell E., Woodfield L. and Nevill A. M., Increasing physical activity levels in primary school physical education: The SHARP principles Model, in *Preventive Medicine Reports*, vol. 3, June 2016: 7-13.

retrospective memory, 3) explicit/declarative – memory for facts, consciously recalled, further divided into a) episodic memory – life events, and b) semantic memory – facts, meanings, concepts about the external world, controlled and stored in the temporal lobe and hippocampus, and 4) procedural/implicit memory – memory for skills. This memory has the capacity to remember the skills acquired, so that after a certain time of non-practice, or some brain lesions, it is possible to recover the lost ability. This ability can be stored without any conscious awareness, so that the skilled actions can be performed almost automatically. This is the case of motor actions controlled by a large range of brain areas: motor cortex (the part of the brain which sends signals to the muscle of the body and is responsible for planning and executing movements), the basal glanglia (a structure deep inside the brain which is associated with movement initiation), and the cerebellum (an area at the back of the brain which deals with adaptation). Especially aerobic exercises promote adult neurogenesis by increasing the production of neurotrophic factors. Furthermore, if these exercises go over a time of several months, clinically significant improvements in executive function (i.e. the cognitive control of behavior) as well as a considerable increase in the grey matter volume is noted in the pre-frontal cortex and hippocampus. A moderate improvement is also noted in the anterior cingulated cortex, parietal cortex, cerebellum, caudate nucleus, and nucleus accumbens.[45]

Muscle memory starts its function when one practices a specific motor task many times until this activity is fixed in the memory; thus a long-term muscle memory has been created, and the subject can perform that skill unconsciously. For instance, riding a bike, or playing a musical instrument, or typing on a keyboard or doing automatically the simple many everyday activities are stored automatically into our implicit memory, so that the moment we have achieved a satisfactory level in those skills, we perform them without thinking and without any effort. Muscle memory has also another beneficial effect, in the sense that, even if we do not practice those activities for a certain period of time, our brain will not forget the exact movements related to these skills, since they are stored into the long-term muscle memory. In addition, because our brain has changed its structure by adding new nuclei during the training period, a permanent physiological change in muscle fibers permits to restart performing the skill, even after a certain period of detraining. This new theory is in contrast with the old one, which believed that after a period of detraining, it was difficult to restart with that skill, since the new nuclei had been lost. Skill memory helps us and shows that the skilled actions stored unconsciously into the long-term muscle memory (implicit memory) will be performed automatically even after a period of detraining. The many areas of the brain (motor cortex – sends signals to the muscle involved for executing the movements –, the basal ganglia – associated with movement initiation –, and the cerebellum – it deals with adaptation –), responsible for skill memory, by working together, help us remember and perform those skills even after an untrained period. These paths, while engaged in motor exercises, change their cerebral structure by developing new connections (synapses) between the neurons. The cerebral evolution of neural processes continues even after stopping the exercise. Evolution in the brain starts soon after the first phases of the activity, when the movements are still slow and uncertain or stiff and uncontrolled, when the exercise is disrupted because attention is very poor. Later, as practice increases, movements become smoother and more coordinated and, finally, the task will be performed unconsciously. In this phase the basal glanglia plays a decisive role in both learning and memory, especially in reference to stimulus-response associations and to the formation of habits. Its connections increase greatly during the process involving the learning of a motor task.

Going back to our primary aim, that is, the importance of enhancing physical education especially with young children, we have to say that, by reinforcing our muscles with as many nuclei as possible, we offer children the chance to build up a better life which will help them to face senescence with a positive attitude. In fact, as said before, even though building muscle is not

[45] Robinson T.E. & Kolb B. , Alternations in the morphology of dendrites and dendritic spines in the nucleus accumbens and prefrontal cortex following repeated treatment with amphetamine or cocaine, in *European Journal of* Neuroscience, 11: 1598-1604.

impossible in our later years, it is certainly harder. Then, another positive aspect is related to a proper training period, that is, after a detraining period, it will be easier to re-gain the first efficiency achieved during the encoding stage. An important condition to be focused on is the one related to the two types of memory: a) gross (Gross motor skills are large movements of the body that use large muscles to produce coordinated movements, for example walking, running, sitting, throwing and crawling. Children learn new gross motor skills by practicing them until the skill is mastered) and b) fine motor skills (transitive movements as simple movements used during every-day actions and using some tools as for example to brush teeth, to buckle shoes, to hold a pen, etc.; they are planned by the premotor cortex, which creates motor programs through the activation of the motor cortex).

> Infant gross motor development is vital to adaptive function and predictive of both cognitive outcomes and neuro- developmental disorders. However, little is known about neural systems underlying the emergence of walking and general gross motor abilities. Using resting state fcMRI, we identified functional brain networks associated with walking and gross motor scores in a mixed cross-sectional and longitudinal cohort of infants at high and low risk for autism spectrum disorder, who represent a dimensionally distributed range of motor function. At age 12 months, functional connectivity of motor and default mode networks was correlated with walking, whereas dorsal attention and posterior cingulo-opercular networks were implicated at age 24 months. Analyses of general gross motor function also revealed involvement of motor and default mode networks at 12 and 24 months, with dorsal attention, cingulo-opercular, frontoparietal, and subcortical networks additionally implicated at 24 months. These findings suggest that changes in network-level brain-behavior relationships underlie the emergence and consolidation of walking and gross motor abilities in the toddler period.[46]

When learning both simple (fine) or complex (gross) motor skills, children help their performance by instructing themselves in a way that each act is directed by their words. In their article, Parsla Vintere and al. by examining the role of self-instruction in preschool dance class children (six children) when performing gross-motor chains, found that self-instruction was associated with faster response acquisition. Most authors have been concentrating on the role of self-instruction mostly regarded fine motor chains, achieving the conclusion that complex tasks are better performed if the subjects direct the action with the help of verbal behavior.

> The pooled data show a faster acquisition curve for the procedure containing self-instruction compared to one that did not. Thus, very early in the gross-motor chain process, self instruction was associated with greater performance accuracy than the no-self-instruction condition.[47]

7) Self-instruction: Piaget, Vygotsky, Lurija and Fodor

As Piaget, Vygotsky, Lurija and Fodor said, even considering private speech from different points of view, self-instruction is a kind of guide which reinforces memory and controls those actions that need concentration. When children have acquired some language, private speech aids them in different types of self-guidance and self-regulation, as for example, when they need to be helped because the task they are performing is difficult. Even adult people use self-instruction when they need a support. “In general,” , says Piaget, “inner speech serves to assert, to state objective

---

[46] Marrus N. et al., Walking, Gross Motor Development, and Brain Functional Connectivity in Infants and Toddlers, in *Cerebral Cortex* , Feb. 1, 2018: 750-763; Grissmer D. et al., Fine Motor Skills And Early Comprehension Of The World: Two New School Readiness Indicators, in *Developmental Psychology*, 46.5, 2010: 1008-1017.

[47] Parsla V. et al.,Gross-Motor Skill Acquisition By Preschool Dance Students Under Self-Instruction Procedures in *Journal of Applied Behavior Analysis*, 37, 2004: 305-322; cfr. Grissmer D. et al., Fine Motor Skills and Early Comprehension of the World: two New School Readiness indicators, in *Developmental Psychology*, 46.5. 2010: 1008-1017; Marrus N. et al. Walking, Gross Motor Development, and Brain Functional Connectivity in Infants and Toddlers, in *Cerebral Cortex*, February 1, 28(2), 2018: 750-763.

facts, to convey information, and "… words are closely bound up with cognition. … Language expresses commands or desires, and serves to criticize or to threaten, in a word to arouse feelings and provoke action." When Piaget analyzes the ego-centric speech of children, he affirms that this kind of speech fluctuates between an inner and a social language: "All the language that is bound up with action, with handicraft, and especially with play, will tend to become more socialized."[48] Children use it when performing an activity mostly guided by commands, because this is the only type of language they have to communicate. The child thinks ego-centrically, because of "1) the absence of any sustained social intercourse, and 2) the fact that the language used in the fundamental activity of the child – play – is one of gestures, movement and mimicry as much as of words."[49] Commands are the most common linguistic structures the child uses "to accompany and reinforce individual activity" (: 18).

Piaget

The child does not in the first instance communicate with his fellow-beings in order to share thoughts and reflections; he does so in order to play. The result is that the part played by intellectual interchange is reduced to the strictly necessary minimum. The rest of language will only assist action, and will consist of command, etc. p. 27

… gesture cannot express everything. Intellectual processes, therefore, will remain ego-centric, whereas commands etc., all the language that is bound up with action, with handicraft, and especially with play, will tend to become more socialized. 42

6) *Commands*, *requests* and *threats:* In all of these there is definite interaction between one child and another. 6

7) *Questions:* Most questions asked by children among themselves call for an answer and can therefore be classed as socialized speech, with certain reservation to which we shall draw attention later on.

REPETITION (ECHOLALIA). – Everyone knows how, in the first years of life, a child loves to repeat the words he hears, to imitate syllables and sounds, even those of which he hardly understands the meaning. It is not easy to define the function of this imitation in a single formula. From the point of view of behavior, imitation is, according to Claparède, an ideomotor adaptation by means of which the child reproduces and then simulates the movements and ideas of those around him. But from the point of view of personality and from the social point of view, imitation would seem to be, as Janet and Baldwin maintain, a confusion between the I and the not-I, between the activity of one's own body and that of other people's bodies. At his most imitative stage, the child mimics with his whole being, identifying himself with his model. 113

[48] Piaget J., *The Language and Thought of the Child*, Harcourt, Brace & Company, INC, New York, 1926: 46.
[49] idem

When Piaget examines the emergence of language, he stresses that "without originally imitating others and without the desire to call his parents and to influence them, the child would probably never learn to talk; in a sense, then, the monologue is due only to return shock of words acquired in relation to other people. With no doubt, without this imitation phase the child would never learn either the language or the social ways of life belonging to his context." By practicing imitation, even when he is older, as it is the case of our examined children (from 3 to 5 years old), it seems that this practice helps them any time they have to face a new situation. In so doing, imitation is a way helping him to achieve a better stage of the exercise they are practicing, so to attract the teacher as well as the fellow-beings. At this age, the child is conscious about his imitation, and he does it purposely, and not unconsciously as when he imitated his parents' language during the echolalia phase. At that time, "it should be remembered, however, that throughout the time when he is learning to speak, the child is constantly the victim of a confusion between his own point of view and that of other people."(p. 16). At this age the child is pushed by his will to emerge, to be praised by his teacher and to be imitated by his peers. His energy is regulated by the interest he puts in the task, and is a conscious aspect of his growing personality:

> L'interesse è uno stupefacente regolatore: basta che ci si interessi ad un lavoro per trovare le forze necessarie onde proseguirlo, mentre il disinteresse frena l'erogazione dell'energia.[50]

At this age the child has already acquired a certain notion of time, so, practicing physical education reinforces it, since the child has to move following not only the teacher, but also the other little friends engaged in the exercise. In addition there is the music, too, which has the role to offer a certain harmony to movements. Piaget, when he examines the rise of this notion establishes the two phases the child goes through since the first days of life. That is 1) the sequence of the events and 2) and the interval established among the events. Considering our children, the practice of physical exercises results a good expedient to reinforce their knowledge about time. In fact, by following his own sequence of movements as well as those of the others, the child has to balance time and space, since he has to confine his body into a definite space and meanwhile he has to calculate it in order to share it with the others.

> Cominciando dalla nozione di tempo, essa si presenta sotto due aspetti distinti: l'ordine di successione degli eventi e la durata o intervallo fra eventi ordinate.[51]

Piaget, emphasizes that any acquisition, even though it seems innate, and is helped by the development of the physiological structure of the brain, by giving access to many possibilities, which permit the realization of a task, is principally modeled by environment and experience. He gives the example of his three children who achieved the balance between touch and vision at a different age, because they had been stimulated differently. Under these assumptions, we realized that by offering children the chance to practice physical exercises, we gave them the opportunity to fully utilize their potential while reinforce notions about time, space, social relationship, language and thought.

---

[50] Piaget *Lo sviluppo mentale del bambino*, Piccola biblioteca Einaudi,Torino, 1967: 68.
[51] Piaget: 89.

… il sistema nervoso e la sua maturazione si limitano ad aprire un determinato campo di possibilità, all'interno del quale un certo numero di condotte verrà attualizzato; … ma tale attualizzazione suppone determinate condizioni d'esperienza fisica … e alcune condizioni sociali … e sono queste diverse condizioni a determinare il completamento di ciò chela maturazione rende semplicemente possibile.[52]

By following Vygotskij thought, any time the child has to develop something new and difficult, even at an older age, he will go back to the ego-centric and *syncretic* phase, so to guide his behavior. The instruction the child receives to develop a certain activity, affirms Vygotskij, is a language the child, then, will use not to communicate with the others, but to direct his action. By linking words (in our case commands) and behavior (in our case the teacher's physical positions), the child builds up notions about space (the place in which he has to move), time (the rhythm of the music), his/her body, his/her strength, his/her concentration, his/her attitude toward this subject (PE). In sum, all these features contribute to shape a new notion through generalization, thus giving him/her the chance to combine language and thought.

Therefore, we all have reasons to consider a word meaning not only as a union of thought and speech, but also a union of generalization and communication, thought and communication.[53]

During the practice of a physical exercise, the commands given by the teacher, his position as a model to be imitated as well as the movements of the other children in the group give a verbal and a behavioral input to each child; an input which, by reinforcing and enlarging cognition, gives children the opportunity to execute the exercise in accordance with the instructions received. Language, Lurija says, exerts a cognitive control over the development of thought by offering the child the chance to shape new behavioral patterns. Rather, when the child is too young (2 years old) his linguistic system is not yet developed, so, any command, which wants to regulate and direct his action, is vain.

Vediamo quindi se il linguaggio del bambino sia ora sufficientemente sviluppato e se i processi neurodinamici che vi presiedono siano ora sufficientemente perfetti da renderlo capace di regolare le sue reazioni motorie attraverso il linguaggio piuttosto che per mezzo di alter influenze di natura più costante e diretta, come la stimolazione cinestetica derivante dal contatto con la peretta di gomma. Ogni tentativo di utilizzare il ruolo regolatore del linguaggio del bambino, in soggetti tra i due anni e i due anni e mezzo, fu un fallimento. Il sistema di linguaggio nei bambini di questa età è ancora troppo imperfetto, e riuscire a ottenere reazioni verbali, anche le più semplici, rispetto a un segnale condizionato, si dimostrò impossibile: d'altra parte, questi tentativi finivano con l'essere un impedimento alle reazioni motorie organizzate del bambino.[54]

… il comportamento del bambino può essere influenzato *dall'impulso verbale innervante* che consiste nell'innervazione di ben definiti organi del linguaggio e che crea un centro di eccitazione nell'area motorio-verbale della corteccia cerebrale. … il linguaggio del bambino si rivela come un regolatore del comportamento.[55]

At the age of 3 to 5, the child has already developed, as Lurija says, a conditioned connection derived by verbal instructions; instructions, which the child repeats and uses in order to give commands to himself when he wants to pursue some goals during an "active" situation. An "active" situation means that the child is asked to develop a task. Viewed under this perspective, language

[52] Idem 123.
[53] Vigotsky L., *Thought and Language*, The MIT Press, Cambridge, Massachusetts, 1987: 9.
[54] Lurija A.R., *Linguaggio e comportamento*, Editori Riuniti Paideia, 1984: 70-74.
[55] Lurija A.R., *Linguaggio e comportamento*, Editori Riuniti Paideia, 1984: 55.

favours not only the structure of the mental processes, but also stimulates behavior.

> Abbiamo visto come il linguaggio sia parte integrante della struttura dei processi mentali e quanto sia potente come mezzo di regolazione del comportamento umano (37). … Da una parte, il comportamento successive del bambino può essere influenzato *dall'impulso verbale innervante* che consiste nell'innervazione di ben definiti organi del linguaggio e che crea un centro di eccitazione nell'area motorio-verbale della corteccia cerebrale.[56]

The child's behaviour is stimulated by a verbal innervated input, which provokes the innervations within the cerebral cortex of the organs deputed to language as well as those linked to motion.

Lurija, in order to evaluate the grade of difficulty of a task, controls the child's verbal behavior. He says that the more demanding a task is, the more the child controls it with his speech. This language, he says, is not inner speech or a speech with social intention, rather the child talks just to be sure that his actions are developed in function of his commands. When the task has been acquired properly he does not accompany it verbally any longer.

> … il linguaggio proprio del bambino è strettamente connesso alla sua attività pratica e che,applicando al proprio comportamento I metodi sviluppati nelle relazioni sociali, il bambino comincia a formare nuovi sistemi funzionali, la cu struttura più profonda è legata al linguaggio.[57]

At the age of 4 and half, says Lurija, it is possible for the child to follow verbal commands, because he is able to understand quite a sufficient number of words and easy structures. Consequently he adapts his behavior in order to proceed with the task, and in order to pursue his aim he himself formulates a kind of commands which direct the realization of the task.

> Le prove sperimentali dimostrano che il radicale cambiamento … ha luogo in bambini tra i quattro anni e mezzo e i cinque anni e mezzo. Prima di questa età è assolutamente impossibile elaborare nel bambino un sistema stabile di reazioni motorie, soltanto mediante istruzioni verbali. … egli regola il suo comportamento successivo secondo regole verbali formulate all'interno … .[58]

Going back to the purpose of this essay, which wants to stress the importance of physical education to very young children, in the light of the above assumptions, we realized that the children observed, even during the group execution of the exercises commanded, while imitating the movements suggested by the instructor, repeated by themselves the oral commands received. It was a strategy that helped them to execute the action in accordance to the rhythm of the music, too. Verbal as well as position inputs stimulated action through simulation. Simulation is not just the desire to imitate the other, so, to produce a better exercise, which will attract the teacher's attention. Imitation is the main force that guides children during their physiological as well as cognitive development. Indeed, imitation is also regulated by a precise physiological structure of the brain: the mirror neurons, which allow us to imitate actions, to reproduce facial expressions, to feel what others feel, to understand other people's feelings and so on. Children use this powerful tool to acquire linguistic, social and behavioural cognitions. Within this study (physical education in young children), the role of mirror neurons is strategic, since the child involved in the execution of physical exercises, with the help of these neurons is capable not only to imitate both his fellow-beings and his teacher's movements, but moreover to balance his/her activity in accordance with them. Thus, mirror neurons are activated by either execution or imitation.

---

[56] Lurija:70.
[57] Lurija:22.
[58] Lurija: 75.

> Mirror neurons were discovered over twenty years ago in the ventral premotor region F5 of the macaque monkey. … The key characteristics of mirror neurons are that their activity is modulated both by action execution and action observation, and that this activity shows a degree of action specificity. This distinguishes mirror neurons from other 'motor' or 'sensory' neurons whose discharge is associated with either execution or observation. … Mirror neurons are a class of neuron that modulate their activity both when an individual executes a specific motor act and when they observe the same or similar act performed by another individual.[59]

"Mirror neurons," says Iacoboni in an interview with Lehrer, "are the only brain cells we know of that seem specialized to code the actions of other people and also our own actions. They are obviously essential brain cells for social interactions. Without them, we would likely be blind to the actions, intentions and emotions of other people. The way mirror neurons likely let us understand others is by providing some kind of inner imitation of the actions of other people, which in turn leads us to 'simulate' the intentions and emotions associated with those actions."

> A category of stimuli of great importance for primates, humans in particular, is that formed by actions done by other individuals. If we want to survive, we must understand the actions of others. Furthermore, without action understanding, social organization is impossible. In the case of humans, there is another faculty that depends on the observation of others' actions: imitation learning. Unlike most species, we are able to learn by imitation, and this faculty is at the basis of human culture. In this review we present data on a neuro-physiological mechanism—the mirror-neuron mechanism.[60]

8) Conclusions

Conclusions, which we deemed at first positive, no longer seem so, since the benefits derived from one year course in gymnastic have no immediate results for two reasons:

1) first, one year is too short a time to produce any tangible effect. At an early age, one year course may produce only the habit to move regularly, to organize movements according either to musical rhythm or teacher's instruction or following the other peers. Exercises will help to achieve a gradual harmony when performing some functional tasks (buckle shoes, fasten belts, do all the buttons, clip), or accelerating habitual movements, or, most importantly, when focusing the child's mind on the pleasure of executing some exercises with the aim to refine them.

2) Second, since development can be analyzed from different sides (qualitative, sequential, cumulative, directional, multi-factorial), development is principally individual, in other words, it is not age determined. Each child has his/her own developmental phases. Consequently, it is wrong to compare a child to another only because they have the same age.

> One problem in studying development is that we come to think of age as being development, that age becomes an agent of change, perhaps even *the* agent of change. … We must remember that time itself is not causal and that age merely marks the passage of time or a period of time. Agents of change, such as biological processes or social interactions, function during the passage of time to determine or influence change. This means that we must consider what is happening during a period of time rather than view age as the agent of change.[61]

---

[59] Kilner J.M. and lemon R.N., What We know Currently about Mirror Neurons, in *Current Biology*, dec. 2, 2013: 23 (23); Heyes C., Mesmerising mirror neurons, in *Neuroimage*, 51, 2010: 789-791.
[60] Rizzolatti G. and Craighero L., The Mirror-Neuron System in *Annual Review Neuroscience*, 27, 2004: 169-192.
[61] Keogh J. and Sugden D., 1985, *Movement skill development*, Macmillan, New York: 20.

The only effect we might expect from stimulating young children with a planned physical education program is the one related to their mind, that is to say, to let them understand, love and appreciate movement as a source of good health and, at that age, of pleasure.

> But for your workout to be effective, it must be planned properly. Which means you can't enter the gym and randomly declare, 'Chal aaj chest marte hai', or fool yourself into believing that twenty-five squats in the bathroom will give you a toned butt. Training after all is serious business and if you want tangible results out of it, you must be prepared to put in tangible efforts.[62]

Bibliography

American Journal of Physiology – Endocrinology and Metabolism, September, 2016.
Atwell, P.; Cooke, S.; Yeo, C., 2002, Cerebellar function in consolidation of motor memory, in *Neuron. **34**: 1011–20.*
Bay E., Ontogeny of Stable Speech Areas in the Human Brain, in *Foundations of Language Development* (eds by Eric Lennegerg and Elizabeth Lennegerg), Academic Press, New York, 1975.
Benoit Viollet, The Enegy Sensor AMPK: Adaptations to Exercise, Nutritional and Hormonal Signals, in Spiegelman (eds.), 2017.
Booth F. W. and Chakravarthy M. V., Cost and Consequences of Sedentary Living: New Battleground for an Old Enemy, in *ERIC*, Number: ED470690, 2002 March: 10.
Booth F. W., Lees S. J., Physically Active Subjects Should Be the Control Group, in *Journal of the American College of Sports Medicine*, 2006.
Boström P. et al., A PGC1-α – dependent myokine that drives brown-fat-like development of white fat and thermogenesis, in *Nature*, 481 26 January 2012: 463-468.
Boyden, E.; Katoh, A.; Raymond, J., 2004 Cerebellum-dependent learning: the role of multiple plasticity mechanisms, in *Annu. Rev. Neurosci.* **27**: 581–609.
Brashers-Krug, T; Shadmehr, R.; Bizzi, E., 1996. Consolidation in human motor memory, in *Nature*, **382**: 252–255.
Chakravarthy M. V., Joyner J. M. and Booth F. W., An Obligation for Primary Care Physicians to Prescribe Physical Activity to Sedentary Patience to Reduce the Risk of Chronic Health Conditions, in *Mayo Clin Proceedings*, Vol. 77, February 2002.
Conway, M. A., Pleydell Pearce, C. W., The construction of autobiographical memories in the self memory system, in *Psychological Review*. **107** (2), 2000.
Danner D., Snowdon D. A., et al., Positive Emotions in Early Life and Longevity : Findings from the Nun Study, in *Journal of Personality and Social Psychology*, vol. 80, n. 5, 2001.
Demarin V., Morovic S. and Béné R., Neuroplasticity, in *Periodicum*, vol. 116, n. 2, 2014.
Diwekar Rujuta, *Strength Training*, Westland Publications Private Limited, 2018: loc 102 eBook.
Draganski B., Gaser C., Busch V., Schuierer G.,Bogdah U. & May A., Neuroplasticity: Changes in grey matter induced by training, in *Nature*, vol.427, January 22nd, 2004.
Fagundo A. B. and al. Modulation of Irisin and Physical Activity on Executive Functions in Obesity and Morbid Obesity in *Scientific Report*, 2016, August 1.
Gerstner W., Hebbian Learning and Plasticity, in *From Neuron to Cognition via Computational Neuroscience* (M. arbib and J. Bonaiuto edited by), MIT Press Cambridge, 2011.
Grissmer D. et al., Fine Motor Skills and Early Comprehension of the World: two New School Readiness indicators, in *Developmental Psychology*, 46.5. 2010: 1008-1017;
Hebb D., *Organization of Behavior: A Neuropsychological Theory*, Wiley, New York, 1949.
He Zihong et al., Cardiorespiratory Fitness Response to Regular Exercise, in Spiegelman (eds.) 2017.
Heyes C., Mesmerising, Mirror Neurons, in *Neuroimage*, 51, 2010: 789-791.

[62] Diwekar Rujuta, *Strength Training*, Westland Publications Private Limited, 2018: loc 102 eBook.

Iacono D., et al. The Nun Study – Clinically silent AD, neuronal hypertrophy, and linguistic skills in early life, *Nature* vol. 427, January 2004: 311-312.
Kandel, Eric R.; Schwartz, James H.; Jessell, Thomas M. (2000). *Principles of Neural Science* (Fourth ed.). United State of America: McGraw-Hill: 324.
Keogh J. and Sugden D., 1985, *Movement skill development*, Macmillan, New York: 20.
Kilner J.M. and lemon R.N., What We know Currently about Mirror Neurons, in *Current Biology*, dec. 2, 2013: 23 (23);
Kolb B., Gibb R. and Robinson T. E., Brain Plasticity and Behavior, in *Current Directions in Psychological Science*, vol. 12, n. 1, February 2003.
Kolb B., *Brain Plasticity and Behaviour*, Lawrence Erlbaum Associate Publishers, Mahwah, New Jersey, 1995.
Kolb and Gibb, Brain Plasticity and Behaviour in the Developing Brain, in *Journal Canadian Acad Child Adolescence Psychiatry*, vol. 20 (4), Nov. 2011: 265-276.
Kramer A., Aerobic Exercise Training Increases brain Volume in Aging Humans, in *Journal of Gerontology: Medical Science*, 61(11): 1166-70, December 2006.
Kuypers H., *Anatomy of the descending pathways* (V. Brooks ed.), The Nervous System, handbook of Physiology, vol. 2, Baltimore, Williams and Wilkins, 1981.
Lenneberg E.H., In Search of a Dynamic Theory of Aphasia, in *Foundations of Language Development*, Academic Press, New York, 1975: 12.
Lonsdale, C., Rosenkranz R.R. et al. A systematic review and meta-analysis of interventions designed to increase moderate-to-vigorous physical activity in school physical education lessons, in *Preventive Medicine*, 56, 2013: 152-161.
Lurija A.R., *Linguaggio e comportamento*, Editori Riuniti Paideia, 1984.
McGaugh, JL, The Amygdala modulates the consolidation of memories of emotionally arousing experiences, in *Annual Review of Neuroscience,* 2004, **27** (1): 1–28.
Marrus N. et al., Walking, Gross Motor Development, and Brain Functional Connectivity in Infants and Toddlers, in *Cerebral Cortex* , Feb. 1, 2018: 750-763.
Mishkin, M.; Appenzeller, T., The anatomy of memory, in *Scientific American*,1987, **256** (6): 80–89.
Møller Aage R., *The Malleable Brain*, NovaBiomedical Books, New York, 2009: 173.
Parsla V. et al.,Gross-Motor Skill Acquisition By Preschool Dance Students Under Self-Instruction Procedures in *Journal of Applied Behavior Analysis*, 37, 2004: 305-322;
Pascual-Leone A., Freitas C., Oberman L., Horvath J. C., Halko M. et al., Characterizing brain cortical plasticity and network dynamics across the age-span in health and disease with TMS-EEg and TMS-fMRI, in *Brain Topography*, 24: 302-315.
Piaget J., *Lo sviluppo mentale del bambino*, Piccola biblioteca Einaudi,Torino, 1967.
Piaget J., *The Language and Thought of the Child*, Harcourt, Brace & Company, INC, New York, 1926. .
Powell E., Woodfield L. and Nevill A. M., Increasing physical activity levels in primary school physical education: The SHARP principles Model, in *Preventive Medicine Reports*, vol. 3, June 2016: 7-13.
Rizzolatti G. and Craighero L., The Mirror-Neuron System in *Annual Review Neuroscience*, 27, 2004: 169-192.
Robinson T.E. & Kolb B., Alternations in the morphology of dendrites and dendritic spines in the nucleus accumbens and prefrontal cortex following repeated treatment with amphetamine or cocaine, in *European Journal of Neuroscience*,11: 1598-1604.
Sallis JF., McKenzie TL et al., Effects of health-related physical education on academic achievement: project SPARK, in *Res Q Exercise Sport*, Jun., 70 (2), 1999: 127-34.
Sallis F. J. et al . Effects of health-related Physical Education on Academic Achievement: Project SPARK, in *Research Quaterly for exercise and sport*, 70 (2), July 1999: 127-134.
Sejnowski, T. J. The Book of Hebb, in *Neuron*, vol. 24, 1999: 773-776.

Sibley B. A. and Etnier J. L., The Relationship Between Physical Activity and Cognition in Children: A Meta-Analysis, in *Pediatric Exercise Science*, 15, 2003: 243-256.
Spiegelman B. (eds), *Hormones, Metabolism and the Benefits of Exercise*, Springer International Publishing, Switzerland, 2017.
Timmons J. A. et al. Is irisina human exercise gene? In *Nature*, 488, 30 August 2012: 463-468.
Valente-Silva P. and Ruas L. J. Tryptophan-Kynureine Metabolites in Exercise and Mental Health, in Spiegelman (eds.) 2017.
Vigotsky L., *Thought and Language*, The MIT Press, Cambridge, Massachusetts, 1987.
Warrington, E., & Weiskrantz, L. (1973). An analysis of short-term and long-term memory defects in man, in J.A. Deutsch, ed. *The Physiological Basis of Memory*. New York: Academic Press.
Wrann C. D., The Role of FNDC5/Irisin in the Nervous System and as a Mediator for Beneficial Effects of Exercise on the Brain, in Spiegelman (eds.) 2017.
Zarrelli N. The neurologists who fought Alzheimer's by studying nuns' brain, March 24th 2016.
Zhang J. Et al., Exercise-induced irisin in bone and systemic irisin administration reveal new regulatory mechanism of bone metabolism, in *Bone Research*, 2017, 5:56.