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DANCE AND NEUROSCIENCE: THE PHENOMENA OF NEUROPLASTICITY INVOLVED

DANZA E NEUROSCIENZA: I FENOMENI DELLA NEUROPLASTICITÀ COINVOLTI

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Abstract

Research carried out in the field of neuroscience has shown which functions the brain uses to learn effectively and satisfactorily. Furthermore, it is possible to overcome the decay of intellectual faculties even in old age through lifelong learning. This is all due to neuroplasticity. To prevent brain aging, it is useful to carry out both cognitive and motor activities such as dancing. Therefore, the main objective of this study was to demonstrate that dance can induce neuroplasticity in both young and elderly subjects at the cerebellar, hippocampal and vestibular system levels by modifying their structure. The advances made in recent years by neuroscience show that learning is not reserved only for the younger generations and people with a fully efficient mind, but that it can be implemented in all ages of life with equal effectiveness. Therefore, learning helps to increase neuronal regeneration and avert the effects of aging. The challenge is to transform the old pedagogical models by rethinking education in a perspective of flexibility and personalization that reflects complexity.

La ricerca condotta nel campo delle neuroscienze ha mostrato quali funzioni utilizza il cervello per apprendere in modo efficace e soddisfacente. Inoltre, è possibile superare il decadimento delle facoltà intellettuali anche in età avanzata attraverso l'apprendimento permanente. Tutto ciò è dovuto alla neuroplasticità. Per prevenire l'invecchiamento cerebrale, è utile svolgere attività sia cognitive che motorie come la danza. Pertanto, l'obiettivo principale di questo studio era dimostrare che la danza può indurre neuroplasticità in soggetti sia giovani che anziani a livello del sistema cerebellare, ippocampale e vestibolare modificando la loro struttura. Le neuroscienze hanno dimostrato, attraverso i progressi compiuti negli ultimi anni che l'apprendimento non è caratteristico solo delle giovani generazioni e delle persone con una mente pienamente efficiente, ma può essere attivato in tutte le età della vita con uguale efficienza. Pertanto, l'apprendimento aiuta ad aumentare la rigenerazione neuronale e ad evitare gli effetti dell'invecchiamento. La sfida è trasformare i vecchi modelli pedagogici ripensando l'educazione in una prospettiva di flessibilità e personalizzazione.

Key-words

Neuroscience, neuroplasticity, dance, learning

Neuroscienze, neuroplasticità, danza, apprendimento

Introduction

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Although some scientists as early as the early twentieth century conducted research whose results showed that the brain is capable of reorganizing itself, for years we have remained faithful to the idea that every brain area is responsible for a function, and even if one of this is compromised, its function will have consequences.

In recent years, however, research in neuroscience has shown that the brain is plastic, that it has the ability to reorganize itself and find different solutions to maintain a function or cope with a new situation. In short, learn.

Moshe Feldenkrais already in the 1950s had intuited the great possibilities of the human nervous system and had developed a practical method based on man's innate learning ability.

1. Neuroplasticity

Brain plasticity is defined as the ability of the nervous system to change its structure and functioning over the course of its life, as an adaptation to the diversity of the environment. Although this term is used quite frequently in psychology and neuroscience today, it is not easy to define (Fuchs & Flügge 2014).

When we talk about brain plasticity, we mostly refer to the changes that occur at different levels in the nervous system: molecular structures, changes in genetic expression and in individual behavior. We call this brain plasticity, which is then the plasticity of neurons, neuroplasticity. Neuroplasticity allows neurons to regenerate both anatomically and functionally and to form new synaptic connections. On the other hand, what is known as neuronal plasticity represents the brain's ability to recover from damage and restructure itself (Kleim & Jones 2008).

This process of cerebral, neuronal plasticity and neuroplasticity is nothing more than an adaptive process of the nervous system that allows the brain to recover from disorders or injuries, and can reduce the effects of structural alterations produced by pathologies such as multiple sclerosis, Parkinson's, cognitive impairment, Alzheimer's disease, dyslexia, attention-deficit / hyperactivity disorder (ADHD), insomnia, etc.

2. Synaptic plasticity

Synaptic plasticity is part of the phenomenon of plasticity. When the brain is engaged in a new learning experience, a series of neural connections are established. These pathways or neural circuits constitute pathways of neurons created in the brain by learning and practicing what we have learned. These synapses or pathways of communication can be regenerated throughout life. Therefore, each time new knowledge is acquired, the communication or synaptic transmission between the involved neurons is strengthened. The better the communication between neurons, the more efficiently the electrical signal will travel a new path (Kolb et al, 2003). For example, when you try to learn how to use a new tool, new connections are established between certain neurons. The neurons of the visual cortex are responsible for color and buttons, those of the auditory cortex are responsible for sounds, etc. To do this, these neurons are evoked repeatedly, so that the neural circuit is revisited and neuronal transmission between the neurons involved is restored, so that each new attempt improves the efficiency of synaptic transmission. Therefore, synaptic plasticity is perhaps the pillar that neuroscience and psychology are trying to investigate to give us more information about our most curious and unknown organ, the brain, thus explaining our brain plasticity (d'Aquin et al, 2022).

3. Neurogenesis

Whereas synaptic plasticity is achieved by improving communication in the synapse between existing neurons, neurogenesis refers to the birth and proliferation of new neurons in the brain. For a long time the idea of neuronal regeneration in adults was considered nonsense, science and scientists have believed that neurons die and are only replaced by new ones. The situation changed in the 1960s, the scientific community still believed that the adult human brain was rigid and static. Marian Diamond, on the other hand, in 1964 published a study - Chemical and Anatomical Plasticity of the Brain -, together with three colleagues (psychologists Mark Rosenzweig and David Krech, and biochemist Edward Bennett) where he showed for the first time that in adults even the brain had changed anatomically (Bennett et al, 1964). In short, the brain was adaptive and plastic, thanks to knowledge, but especially in recent years the existence of neurogenesis has allowed it to be scientifically verified. We now know what happens when the stem cells found in the dentate gyrus, in the hippocampus and perhaps in the prefrontal cortex, divide into two cells: a stem cell and a cell that will become a fully equipped stem neuron, with axons and dendrites. These new neurons migrate to different (even distant) areas of the brain, where they are required, thus allowing the brain to maintain its neuronal capacity (Lie et al, 2004). Considering the multiple circumstances that life offers us, we might wonder if the brain changes every time we learn something. Research suggests this is not the case. It appears that the brain will acquire new knowledge, and thus realize its potential for plasticity, only if what we have learned again leads to behavioral improvement. Through practice, communication between neurons improves and cognition becomes faster and faster, because neurons strengthen the communication bridges between them.

4. Compensatory Functional Plasticity

The neurobiological decline that accompanies aging is well documented in the scientific literature and explains why older people perform worse than younger people on neurocognitive performance tests. But surprisingly, not all older performers are inferior, some manage to do just as well as their younger counterparts. This unexpected difference in the performance of a subset of individuals of the same age has been scientifically investigated, finding that when processing new information, higher performing seniors use the same brain regions that younger people use, but they also use parts of the brain that neither the neither the young nor the rest of the elderly use. The researchers reflected on this over-exploitation of the best performing brain regions in the elderly and concluded that the use of new cognitive resources reflects a compensatory strategy. In the presence of age-related deficits and the decrease in synaptic plasticity that accompany aging, the brain once again openly shows its plasticity to reorganize its neurocognitive networks. Studies show that the brain reaches this functional solution through the activation of other neural pathways, thus activating the regions of both hemispheres more often (Kolb & Whishaw, 2008).

5. Operation and behavior

We have seen that plasticity is the brain's ability to alter its biological, chemical and physical properties. However, when the brain changes, functioning and behavior change along a parallel path. In recent years we have learned that brain alterations at the genetic or synaptic level are caused both by experience and by a wide variety of environmental factors. New insights lie at the heart of plasticity, with brain alterations probably the most tangible manifestation of learning, which in turn has been made available to the brain from the environment. New learning occurs in many ways, for many reasons, and at any time throughout our life. For example, children acquire new knowledge in large quantities, producing significant brain changes in these moments of intensive learning. New learning can also arise in the presence of supervening neurological damage, for example due to injury or stroke, when the functions supported by a damaged brain area are compromised and must be relearned. The need to continuously acquire new knowledge can be intrinsic to the person and can be guided by his thirst for knowledge. The multiplicity of circumstances in which new learning occurs makes us wonder if the brain will change every time something is learned. Research suggests this is not the case. It appears that the brain will acquire new knowledge, and thus realize its potential for plasticity, if the new learning leads to better behavior. To learn to physiologically mark the brain, learning must lead to changes in behavior. In other words, new learning must be relevant and necessary behavior. For example, the new learning that guarantees survival will be integrated by the organism and adopted as an appropriate behavior. As a result, the brain will have changed. Perhaps most important is the degree to which a learning experience is rewarding. For example, learning through interactive games is particularly useful for improving brain plasticity. Indeed, this form of learning has been shown to increase the activity of the prefrontal cortex (Cotman & Berchtold, 2002).

6. Conditions that induce plasticity

The models of plasticity differ according to age and, in reality, much remains to be discovered on the interaction between the type of activity that induces the plasticity and the age of the subject. However, we know that intellectual and mental activity induces brain plasticity when applied to both healthy elderly people and if applied to elderly people with a neurodegenerative disease. More importantly, it appears that the brain is susceptible to changes, both positive and negative, even before the birth of its carrier. Animal studies show that when pregnant mothers establish themselves in an environment rich in positive stimuli, their offspring have a greater number of synapses in specific regions of the brain. Conversely, when stressful light was applied to pregnant females, their offspring were found to display a reduced number of neurons in the prefrontal cortex. Furthermore, it appears that the prefrontal cortex is more sensitive to environmental influences than the rest of the brain (Gibb, Gonzalez, Wegenast, & Kolb, 2010). It seems, therefore, that the environment can induce changes in neuronal gene expression. Some genes are affected even in a very short stimulation period, other additional genes are affected during a longer stimulation period, while others do not undergo any changes or, if they do, their tendency is reversed. Although the common use of the term "plasticity" has a positive connotation, plasticity actually refers to all the changes that occur in the brain, some of which can occur together with altered functionality and behavior. Cognitive training seems ideal for inducing brain plasticity. It provides the systematic practice necessary for the creation of new neural circuits and for the strengthening of synaptic connections between neurons. However, as we have seen, in the absence of a tangible benefit from the behavior, the brain will not learn effectively. Hence the importance of personalizing the objectives relevant to training.

7. Lifelong learningt

Merzenich argues that the structure of the brain and its cognitions can be improved through proper exercise. Brain maps change based on what we do during our life; above all, they are capable of changing at any age. Starting from the idea that learning consists in creating bonds between neurons through their simultaneous and repeated activation, Merzenich developed a theory according to which the structure can be modified by experience: this means that even people with congenital problems or lesions in certain areas of the brain can develop new neuronal connections.
It is therefore essential to engage the brain in new tasks that constitute a challenge to combat disuse; doing activities that require attention and concentration to help the brain sort out the confused signals; carry out activities capable of activating the production of neuro modulators to regulate their production; engaging in activities that have become difficult to perform, rather than avoiding them, to eliminate compensatory adaptive behaviors. To prevent brain aging, it is useful to carry out both

cognitive and motor activities. The most effective activities are those that require a distinction between sensory signals and the use of this information to achieve increasingly difficult goals. They should be new and challenging: learning to play a new instrument, learning a foreign language, learning juggling, completing a difficult puzzle, playing ping pong, dancing (Merzenich, 2005).

8. Dance and neuroscience

Dance can be defined as the movement of one or more bodies in an organized or improvised choreography with or without accompanying sound (Bl¨asing, et al, 2012). Dance is universal in all human cultures and was already known 1.8 million years ago (Hanna, 1979). Throughout history, dance has played a pivotal role in cultural (Lienard & Boyer 2006) and social (Grammer, et al. 2011) practices and has also developed into an art and performance form. Dance provides a unique model for studying how the brain integrates movement and sound and how motor development joins artistic creativity and performance. The practice of dance involves, in the long term, sensorimotor skills and it is possible to quantify the type and duration of the training.

As such, the study of dance offers a unique window to study the plasticity of the human brain and the interaction between the brain and behavior.

Although several studies have examined the behavioral basis of dance, (Calvo-Merino, Cross, & Jola, 2010) there are few works that have studied the brain basis of dance (Krasnow et al. 2011).

Dancers often learn choreography by watching others perform and observing their own actions to perfect the movements. Consequently, scientific research on dance observation has been influenced by studies on the "mirror neuron system" in primates and humans and, in particular, starting from the idea that this network of neurons supports observation and simulation. of the actions of others (Rizzolatti & Craighero, 2004).

The human action observation network involves the premotor and parietal cortices, which can be involved in the simulation of the action together with the supplementary motor area, superior temporal sulcus and primary motor cortex (Kruger, et al. 2014).

Investigating the brain activity of the dancers as they observe that the dance performances provided information on how dance training activates the action of observation and simulation networks. For this purpose, the researchers used functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) methods. Whereas fMRI offers fine spatial resolution, EEG offers fine temporal resolution. (Mulert & Lemieux, 2010).

9. Brain areas involved in the phenomenon of neuroplasticity in dance

Starting from the idea that learning consists in creating new bonds between neurons through their simultaneous and repeated activation, the neuronal structure can be modified by experience. To prevent brain aging, it is useful to carry out both cognitive and motor activities such as dancing. Therefore, the main objective of this study was to be able to demonstrate that dance can affect brain plasticity and balance conditions, both in young and old subjects.

The cerebellum, the hippocampus and the vestibular system are the anatomical structures mainly involved in the structural changes of the brain and in maintaining balance.

The cerebellum resides in the posterior part of the brain, protected by a structure, the posterior cranial fossa. The cerebellum consists of two lateral cerebellar hemispheres at the center of which is the worm. The cerebellum has a portion of gray matter, which resides on the surface and forms that folded lining, known as the cerebellar cortex, and a portion of white matter, which takes place in the deeper layers of the cerebellum and represents the seat of the cerebellar nuclei. It divides into three lobes:

the anterior lobe, the posterior lobe and the flocculonodular lobe, and two fissures: the primary fissure and the posterolateral fissure. The primary fissure, which separates the anterior lobe from the posterior lobe; the posterolateral fissure, on the other hand, is the fissure that separates the posterior lobe from the flocculonodular lobe. The cerebellum is also divided into three functional areas: the cerebro-cerebellum, involved in the mechanisms of motor learning and coordination of voluntary muscles; the spino-cerebellum, regulates the movements of the body and helps the cerebro-cerebellum in motor learning; the vestibule-cerebellum, presides over the control of balance and posture. The cerebellar nuclei are four groups of neurons with specific functions and are: dentate nucleus, which functionally belongs to the cerebro-cerebellum; emboliform nucleus, which functionally belongs to the spino-cerebellum; globose nucleus, belonging to the spino-cerebellum; core of the roof, belonging to the vestibule-cerebellum. From the functional point of view, the cerebellum is important above all for its motor functions, in fact it is involved in the processes of: coordination of voluntary muscles; balance and posture regulation (presides over postural adjustments, in order to maintain balance); motor learning. The hippocampus is part of the limbic system and is located on the medial portion of the temporal lobe, in an internal fold of the latter. The hippocampus proper (or Ammon's horn) is the main component of the hippocampus. On the hippocampus proper, 4 regions are identified, called CA1, CA2, CA3 and CA4. The first three constitute the center of long-term memory, while the dentate gyrus is located at the level of the CA4 region. The CA2 region is the one with the most compact pyramidal cell layer, even if it completely lacks the afferents from the muscoid fibers of the granular cells of the dentate gyrus. The subicolo represents the lower structural component of the hippocampus; it extends between the entorhinal cortex and the CA1 region of the proper hippocampus. It is involved in working memory, in particular the visual spatial memory which we will later see to be important for improving balance in elderly subjects. The hippocampus is involved in cognitive processes such as: memory, spatial memory, orientation and the learning of new information and movements.

The vestibular system is a structure of the inner ear specifically responsible for controlling balance. The vestibular apparatus consists of two elements: the vestibule and the semicircular canals. The vestibule includes two characteristic vesicles: an upper one, called the utricle, and a lower one, called the saccule. The semicircular canals are three curved ducts positioned above the vestibule, thus constituting the upper portion of the vestibular apparatus. At the base of each semicircular canal there is a small dilation, which is called the ampoule. In this case, the utricle and saccule control the so-called static equilibrium, that is the equilibrium in the moments in which the body is motionless or moves in a straight line, while the three semicircular canals regulate the so-called dynamic equilibrium, that is the equilibrium for the moments in which the body performs rotational movements. The three anatomical structures described above are the most important structures responsible for controlling and maintaining the ability to balance, which is of fundamental importance in dance. From a theoretical point of view, balance is a coordinative capacity. Coordination skills concern the processes that organize, control and regulate movement and depend on the degree of maturation of the central and peripheral nervous system, these skills determine the type and quality of the motor response and are in turn divided into general coordination skills, and special. The ability to balance, therefore, allows us, through reflex, automated or voluntary adjustments, to maintain a static position or to perform a movement without falling, reacting to any imbalance factors.

10. Ability of dance to induce neuroplasticity in young and old subjects

In line with the aim of this work, which is to verify whether dance can induce neuroplasticity at the level of the aforementioned nervous structures and also observe whether the balance skills also improve, we have conducted two preliminary studies.

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The goal of the first study was to clarify the differences between professional dancers and the normal population in terms of brain structure, visual spatial orientation skills and general balance skills. Two groups were compared, one consisting of 20 dancers aged between 18 and 35 and a second group consisting of 20 non-dancers of the same age. The behavioral tests performed were the clinical balance test (CBT) for the assessment of balance and the triangle completion test for the assessment of spatial orientation. To verify the morphological changes in the brain, magnetic resonance imaging with voxel-based morphometry was performed, an analysis technique used to highlight the differences in gray matter volumes in various areas of the brain. The CBT test consisted of standing upright on stable and unstable surfaces, and walking with eyes closed and open. The conditions of standing (static) included: standing upright on one or two legs either on stable surfaces such as floors, or unstable such as soft surfaces, with eyes open or closed. Instead the dynamic conditions included: walking back and forth first inside a polygon with open eyes, then on a 4m long line; walk forward on a 4m line with eyes closed. The CBT test, consisting of 30 items, of which 14 assessed static balance, 16 assessed dynamic balance and 8 tasks were performed with eyes closed, amounted to a maximum of 90 points and each condition could be assigned a minimum of 0 up to a maximum of 3 points. In each of the static conditions the participants were instructed to maintain the required position for 15 seconds, while in the dynamic conditions there was no time required and the participants were simply asked to walk at their own pace.
The first results obtained from the balance assessment test showed that the dancers had better balance performance in both static and dynamic conditions. These results were corroborated by functional magnetic resonance studies from which the increase in gray matter volumes was observed for some anatomical structures, in particular in the regions that contribute to maintaining balance and the capacity for spatial orientation. Increased volumes of gray matter were found in dancers in regions that contribute to balance and spatial orientation skills, such as the right posterior cerebellar hemisphere, the worm, and the right hippocampus and parahippocampus regions, particularly in the medial entorhinal cortex, on the other hand, smaller volumes of gray matter were found in the anterior lobes of the cerebellum. Furthermore, it should be emphasized not only that we have observed changes in the structures responsible for equilibrium such as the cerebellum, but we have also noticed an increase in gray matter in the caudal part of the cortex, area 24 of Broadman's classification (cingulate motor cortex). . From functional MRI studies it is known that the motor cortex and cerebellum are active during coordinative movements, along with the associative, sensory and motor regions of the cortex. And since such coordinative movements are a fundamental element of ballet, the discovery of a greater volume of this brain region in dancers is in line with what was observed in the study. And it is for this reason that dancers are able to maintain balance better since there is also an increase in the cortex and these increases in volume are due to processes of neurogenesis, synaptogenesis, etc. This increase in volume is caused by the possible neurobiological mechanisms observed at the basis of the changes in the gray matter such as neurogenesis (new neurons are formed), synaptogenesis (new synapses), hypertrophy of glial cells (increase) and angiogenesis (formation of new vessels). In particular, a neurogenesis was observed for the hippocampus of the dancers, which occurs mainly in the dentate gyrus of the hippocampus. Interestingly, only the dancers showed an increase in this brain region.
This study showed that motor learning of complex and acrobatic skills generates new synapses in the cerebellar cortex. On the contrary, simple physical exercise leads to a greater density of blood vessels in the cerebellum, exercise alone in fact only causes angiogenesis while dancing not only increases the volumes of the brain structures but creates new synapses, new neurons for which it also improves the ability to balance.
In the second study, the effects of two training programs on hippocampal plasticity and balance skills in elderly subjects were compared. The hippocampus is of particular interest in this study as this brain structure is influenced by brain aging. It plays a key role in the main cognitive processes such as

memory and learning, and is involved in maintaining balance, a fundamental daily function, crucial for well-being and quality of life. An imbalance often results in falls, which is a major health problem and a major risk factor with consequences on both morbidity (and even mortality) and health costs.
The survey conducted compared two groups: the first for which a dance training was planned consisting of 15 subjects between the ages of 60 and 80, and another group that carried out a fitness training consisting of 15 subjects of the same age.
The methods used to observe the volumes of the hippocampal regions were functional magnetic resonance imaging studies and voxel-based morphometry.
The ability to balance was assessed by means of a sensory organization test (stabilometry). All this took place in 6 months. Training was scheduled twice a week for both groups. Each dance or fitness class lasted 90 minutes. The content of the dance lessons involved learning choreographies that changed constantly and that the participants had to memorize accurately. The training focused on simple longitudinal turns, somersaults, changes in the center of gravity, standing on one leg, jumps or skips, some dance steps such as chassee, mambo, cha cha, jazz square. The program for the fitness group included resistance training, strength and endurance training, and flexibility training (stretching and mobility).
The first results obtained by observing the magnetic resonance images, show that, in both groups, the volume of the left hippocampus increased, especially in the areas CA1, CA2 and in the subiculum, while only the dancers showed further increases in volume in the lap. dentate (CA4) left and in the right subiculum. Another result obtained from the tests carried out was the improvement in the use of all three sensory systems (visual, vestibular and somatosensory), only in the dance group.
This study, like the previous one, highlights morphological and structural changes in some brain areas. In addition to this, only the dance group scored significantly higher in the balance assessment tests and only the dance group improved in all three sensory systems involved. This would indicate that dance guides all three senses and presumably could also improve the integration of sensorimotor, visual and vestibular information.
Furthermore, it was observed from functional magnetic resonance image studies that only the dance group showed volume increases in multiple subfields of the hippocampus. The results, therefore, show that both dance and fitness training can induce plasticity of the hippocampus in the elderly, but that only dance training has improved the ability to balance in elderly subjects. An interesting aspect of this study is that it has been hypothesized that dance training could be more effective than fitness training in reducing or delaying the risk of neurodegenerative diseases such as Alzheimer's.

11. Conclusions

The progress made in recent years by neuroscience shows that learning is not reserved only for the younger generations and people with a fully efficient mind, but that it can be implemented in all ages of life with equal effectiveness; and, more importantly, that learning always contributes to increasing neuronal regeneration and averting the effects of aging (Guglielman, 2012). The main objective of this document was to provide a focused view of the research conducted to date in the field of dance and the brain. To this end, preliminary results of two studies on the observation of the action of dance, on brain plasticity and associated structures were presented.
Research on dance and the brain promises to provide both a better understanding of auditory and motor brain-behavioral development among experienced and non-skilled dancers, as well as brain plasticity. It could also be useful in the development of dance-based therapy programs. The study of dance neuroscience will support a growing multidisciplinary field by providing insight into the interactions between the arts and the brain.
What research on neuroplasticity confirms, is that learning both in young people and in adult and elderly age is more effective if the brain is engaged in new and challenging tasks, in solving problems

and generally in complex activities such as for example dance. Learning is completely dependent on the existence of neuroplasticity, which allows for the retention, representation and processing of new information. The challenge is to transform the old pedagogical models by rethinking education in a perspective of flexibility and personalization that reflects the complexity and fluidity of the real world.
Neuroscience research shows that it is necessary to propose strategies and activities that activate neuroplastic activities to improve cognitive functions and ensure that educational processes constitute an effective, satisfying and motivating experience. It is necessary to change the established mental habits regarding teaching and learning, taking into account the characteristics of the new educational scenarios. Learning has no age, it is a cumulative process that continues throughout life; if the modalities of how we learn change and diversify with age, the ability to learn persists. The application of neuroscience theories on brain plasticity to the field of adult education appears to be relevant for promoting lifelong learning, through the creation of competence-based learning environments, situated learning and the active construction of knowledge; environments in which strategies and activities are proposed that exploit the principles of neuroplasticity to improve cognitive functions and ensure that education in adulthood is a pleasant, rewarding and effective experience.

References

Fuchs, E., & Flügge, G. (2014). Adult Neuroplasticity: More Than 40 Years of Research. *Neural Plast*, 2014, ID 541870

Kleim, J.A., & Jones, T.A. (2008). Principles of experience-dependent neural plasticity: implications for rehabilitation after brain damage. *J Speech Lang Hear Res*, 51, S225-39.

Kolb, B., Gorny, G., Sonderpalm, A., & Robinson, T. E. (2003). Environmental complexity has different effects on the structure of neurons in the prefrontal cortex versus the parietal cortex or nucleus accumbens. *Synapse*, 48, 149–153.

d'Aquin, S., Szonyi, A., Mahn, M., Krabbe, S., Gründemann, J., & Lüthi, A. (2022). Compartmentalized dendritic plasticity during associative learning. *Science*, 15, 376(6590):eabf7052.

Lie, D. C., Song, H., Colamarino, S. A., Ming, G. L., & Gage, F. H. (2004). Neurogenesis in the adult bra New strategies for central nervous system diseases. *Annual Review of Pharmacology Toxicology*, 44, 399 –421.

Bennett, E. L., Diamond, M. C., Krech, D., & Rosenzweig M. R. (1964). Chemical and anatomical plasticity brain. *Science* 30;146(3644):610-9.

Kolb, B., & Whishaw, I. Q. (2008). Fundamentals of human neuropsychology (6th ed.). New York: Worth.

Cotman, C. W., & Berchtold, N. C. (2002). Exercise: A behavioral intervention to enhance brain health and plasticity. *Trends in Neuroscience*, 25, 295–301.

Gibb, R., Gonzalez, C. L. R., Wegenast, W., & Kolb, B. (2010). Tactile stimulation facilitates recovery following cortical injury in adult rats. *Behavioural Brain Research*, 214, 102–107.

Merzenich, M.M. (2005). Change minds for the better. *The Journal of Active Aging*, 6, 22-30.

Bl¨asing, B., Calvo-Merino, B., Cross, E.S., *et al*. (2012). Neurocognitive control in dance perception and performance. *Acta Psychol*, 139**:** 300–308.

Hanna, J.L. (1979). *To Dance IsHuman: A Theory ofNonverbal Communication*. Austin: University of Texas Press.

Lienard, P. & Boyer, P. (2006).Whence collective rituals? Acultural selection model of ritualized behavior. *Am. Anthropol,* 108: 814–827.

Grammer, K., Oberzaucher, E., Holzleitner, I., *et al*. (2011). "Dance: the human body as a dynamic motion system." In *The Implications of Embodiment: Cognition and Communication*. W. Tschacher & C. Bergomi, Eds.: 173–192. Exeter: Imprint Academic.

Krasnow, D., Wilmerding, M. V., Stecyk, S., *et al*. (2011). Biomechanical research in dance: a literature review. *Med. Probl. Perform. Ar.* 26: 3–23.

Calvo-Merino, B., Cross, E. S., & Jola, C. (2010). "Neurocognitive studies of dance." In *The Neurocognition of Dance: Mind, Movement and Motor Skills*. B. Bl¨asing, M. Puttke & T. Schack, Eds.: 151–234. London: Psychology Press.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annu. Rev. Neurosci.* 27**:** 169–192.

Kruger, B., Bischoff, M., Blecker, C., *et al*. (2014). Parietal and premotor cortices: activation reflects imitation accuracy during observation, delayed imitation and concurrent imitation. *NeuroImage* 100: 39–50.

Mulert,C., & Lemieux, L. Eds. (2010). *EEG–fMRI: Physiological Basis, Technique and Applications*. Berlin: Springer.

Guglielman, E. (2012). The Ageing Brain: Neuroplasticity and Lifelong Learning. *eLearning Papers*, 29, 1-7.