The Ageing Brain: Neuroplasticity and Lifelong Learning

The role of adult education is becoming increasingly important in the framework of policies to promote lifelong learning. Adult participation in training activities, however, is still rather low, despite the incentives and initiatives aimed at allowing all citizens access to education and training at all ages in their lives.

Participation tends to decrease concomitantly with increasing age: the major difficulty that elderly people have in learning is due to a deterioration of brain function, causing a progressive weakening of concentration, memory and mental flexibility. Today, advanced researches in neuroscience show that brain ageing may be reversible: the brain is plastic in all stages of life, and its maps can restructure themselves through learning experiences.

1. Learning in mature age

In Europe the percentage of elderly people compared to the average age of the population is constantly increasing: withing the next 30 years, the under 24 population will decrease of 15%; according to World Health Organization’s data, 2 billion people will be aged 60 and older by 2050. Therefore, it is necessary to foster the participation of adult people in lifelong learning activities to contribute reaching Lisbon goals. The Communication Adult learning: It is never too late to learn focuses on the meaning of improving access and quality in adult education for personal development and social inclusion, listing a series of vantages arising from system strategic actions: increased employment opportunities, increased competition, lower costs for social charges and for early retirement; among the effects on individual well-being: self-fulfillment, active ageing, a better health. Adult education has a crucial importance within the active ageing policy and should be recognized terms of vision, priorities and resources (Commission of the European Communities, 2006).

World Health Organization has pointed out how low school levels are correlated to an augmented risk of disability and death in elderly people. Lifelong learning can support these people in acquiring new skills, and developing the awareness and the sense of security needed to live in an autonomous and independent way; in other words, learning contributes to keep the elderly persons active and flexible (WHO, 2002).

However, there is an obstacle to learning in mature age: the mental decline related to the deterioration of brain function, which is determined in the later stage of life. When the age increases, the ability to generate new synapses between neurons in response to external stimuli declines; this ability is the basis of fundamental and complex functions like memory and learning. The brain ageing causes various changes: reduction in brain volume and gray matter in particular, progressive atrophy of neurons and their interconnections, degeneration of cortical regions governing the functions of sensation, cognition, memory and motor...
control, metabolic decline of key neurons and loss of features related to physical and chemical deterioration (OECD, 2007).

The acquiring of new knowledge and skills becomes therefore more and more difficult, and the execution of complex tasks requires more effort than the younger learners. This problem has been addressed both under the neurological and the educational side by the OECD, which in 2001 held in Tokyo the Forum for Learning Science and Brain Research project to discuss issues related to the nature of brain ageing and cognitive function in old age. Data gathered by OECD demonstrate that many cognitive abilities decline between the ages of 20 and 80; this reduction has effect especially on tasks like reading, recognizing letters and words, and generically on memory. The decay begins around age 30 and accelerates after age 50; it is characterized by memory lapses, delays in reasoning, communication difficulties, and similar concepts.

Today the researches in neuroscience show that it is possible to prevent the deterioration of intellectual faculties, and to maintain the functionality of the brain to learn in an effective and satisfactory way even in old age; in short, learning can actually be lifelong. The key word is neuroplasticity.

2. The static model of localization theory

When we talk about neuroplasticity we refer to the change occurring in the brain as the consequence of an experience, involving the transfer of specific functions to cerebral areas other than those originally allocated to them. To better explain the meaning of this term, we have to step back and explain what was the commonly accepted conception of the brain until a few decades ago.

In the past, scientists believed that the different areas of the human brain were predefined and unchangeable and that the production of neurons ceased after the age of development, with the exception of structures dedicated to the memory, that continue to produce neurons throughout adulthood. The brain was considered an organ that, once reached its full development, became static and incapable of further growth and was therefore condemned to a slow and inexorable decline. The notion of plasticity was limited to the so-called critical period, that is the period corresponding to childhood pre-puberty, when the brain is particularly inclined to learn new skills with minimal effort, for example, learning a second language in addition to mother tongue.

For decades the dominant model was represented by localization theory, according to which the cerebral cortex is composed of distinct regions, each one aimed at specific functions: language, vision, hearing, etc. The precursor of this idea was the German neuroanatomist Franz Joseph Gall (1758-1828), who suggested that the cerebral cortex was divided into zones corresponding to the 27 “faculties” recognized by the psychology of the time. The list of “faculties” was quite heterogeneous and included, beside the memory, hope, faith, love, romantic love and similar concepts.

Despite this theory appears rather naive today, it caused a great sensation at that time. The debate came to a turning point with the studies of Broca and Wernicke, two scientists who examined the brain damage suffered by individuals affected by aphasia, and who were the first to postulate the different specializations of the two cerebral hemispheres. Their studies led to the current model, which assigns different functions to different brain areas: the frontal lobes are the neuronal centers that govern the activities of judgment and planning, development of concepts, organization and control of movements; parietal lobes are the centers of primary somatic and sensory information processing, ie those from skin, muscles, joints and internal organs; the temporal lobes collect and process auditory information; the occipital lobes process primaries visual information.

Broca’s and Wernicke’s studies have allowed to confirm and further develop the localization hypothesis of Gall and, through the subsequent experiments, to identify the key functions in the two cerebral hemispheres. According to this model, the right hemisphere of the brain is responsible for processing information in a comprehensive and perceptive-spatial way, while the left hemisphere presides logical-mathematical abilities and symbolic thinking, besides containing the centers of production and comprehension of language. In the following years the representation of the brain has been enriched on the basis of observations showing that the lesions affecting certain parts of the brain cause the loss of specific functions; these studies have made it possible to reconstruct a map of the cerebral cortex.

The localization theory extends to hypothesize a neuropsychological model in which each region of the brain regulates a particular function independently and without interacting with other regions, and that assumes that the structure of the brain is fixed and immutable: a model that compares the brain to a machine, in which each component performs a genetically predetermined function. One consequence of this theory is that if
one of these components is damaged, it can’t be replaced. The obsolescence of the brain is therefore considered an irreversible process.

3. Anatomy of a plastic brain

In the second half of the 20th century began to spread, supported by experimental data, the idea that the brain is sufficiently plastic to be able to reorganize in case of need even in adulthood, and that sensory signals can be processed in areas other than the ones destined to them. For example, people who have suffered damage affecting the language centers of the left hemisphere have a chance to regain the ability to speak normally, thanks to the restructuring of brain areas; tactile signals, in turn, can be processed in the visual cortex and converted in images, as shown by some experiments (Doidge, 2007).

It is commonly believed that the brain loses about 100,000 neurons every day and that this loss is irreversible; actually, the neurons of large size decrease, while small ones are increasing in number. This causes a reduction of plasticity, but does not mean that the cognitive functions are reduced. The concept of neuroplasticity is essential as an approach to therapeutic rehabilitation programs in the event of trauma and brain damage. The human brain is not “wired” with fixed and immutable neuronal circuits; the synaptic brain network and the related structures, including the cerebral cortex, actively reorganize themselves through experience and practice. Neuroplasticity is related to neurogenesis: neurons damaged can be replaced by stem cells (non-specialized cells able to transform into any cell type). The neuronal stem cells reproduce giving rise to exact copies of themselves, continuously and without showing signs of ageing; the neurogenesis process continues uninterruptedly throughout life, until the death of the individual. It is therefore evident that the discovery of neural stem cells was critical to demonstrate that the brain never stops producing new neurons, even in old age; currently scientists are studying the possibility of replacing the damaged brain tissue of adults to recover the functions in the case of degenerative diseases and brain injuries.

On the concept of plasticity Gerald Edelman has developed neural darwinism (or theory of neuronal group selection). It is an evolutionary model according to which the brain maps are not completely predetermined at the genetic level but also depend on the individual experience and the interaction with the environment. Neuronal Darwinism has been developed in the same period in which scientists Michael Merzenich and Jon Kaas demonstrated by experiment that if a cortical map is no longer receiving stimuli, it will be used for other functions, functions generally located in areas adjacent to it, giving rise to phenomena of reorganization of the cerebral cortex (Mahncke, Bronstone & Merzenich, 2006).

4. “Learn a trade for every day”

Neuroplasticity is linked to the concept of competitiveness: if we stop exercising our mental faculties we not only forget them, but the corresponding map is automatically assigned to other functions that we continue to play. We could change the proverb “learn a trade for a rainy day” in: learn a trade for every day, and continue to practice it regularly.

Competitiveness explains why it is so difficult to “unlearn” something: if we have learned a behavior that has become dominant occupying an extended map, it offers resistance to attempts to substitute it with a different behavior, and it prevents that the same map is occupied by other functions. It also explains the difficulty in quitting bad habits, and the importance of learning a behavior in childhood, when brain maps are on the road to be structured.

According to Merzenich, brain structure and cognitive skills can be improved through an appropriate exercise. The brain maps are transformed according to what we do in our lifetime; most importantly, they are able to change at any age, even in adulthood.

Starting from the idea that learning corresponds to create new connections between neurons through their simultaneous and repeated activation, Merzenich has developed a theory that the neuronal structure can be changed by the experience, which means that even people who have congenital problems or lesions in certain brain areas can develop new neural connections. On the basis of these beliefs, Merzenich proposes a set of exercises targeted at people with language disabilities and learning difficulties; the exercises are progressive and are followed by a positive feedback whenever the user reach the objective, in order to keep constant attention and consolidate the achieved result. The feedback, in fact, causes the release of dopamine and acetylcholine, two neurotransmitters that contribute to the reinforcement of the memory; the result is a reshaping of the brain maps.
These exercises have caused significant progress in students’ learning, also with autistic children and elderly people, improving their mental abilities. The basic idea is that it is possible to reopen the “critical period” of the brain plasticity so that even in adulthood brain maps can be “rewired”; this allows, for example, to learn a foreign language in adulthood as easily as in the case of prepubertal children, who learn a language easily and without accent. Merzenich’s system is based on different mental exercises specifically designed and calibrated to improve memory, reasoning and processing speed in older people.

The assumption is that the mental deterioration in elderly people is linked to the loss of memory, which is caused by the difficulty of recording new events due to a decreased speed of information processing and a deterioration in their sharpness and accuracy. The difficulty in finding words, a common phenomenon in elderly people, is reconnected by Merzenich to a form of atrophy which leads to an unclear representation of sounds and words, which consequently induces confused and disorderly memory traces. The exercises are proposed in a playful form and consist of computer activities in which learners must respond to certain stimuli by completing levels of increasing difficulty. Exercises were designed on the basis of studies conducted with experiments and neuroimaging techniques about the restructuring and reorganization of cortical functions. That is why these activities reach the goal of reactivating mental function in elderly people.

5. Neuroplasticity: learning for a lifetime

The current research shows that substantial changes occur in cortical areas and that learning, thought and action deeply transform functional anatomical structures of the brain. The brain ageing is reversible, as neuroplasticity is bidirectional: it can cause the deterioration of the brain or its improvement. The physical, chemical and functional brain decline is caused by changes that give rise to a process of negative plasticity, causing a vicious circle of deterioration that includes four components:

- **Disuse.** The brain functions respond to the “use or lose it” rule; elderly people often limit themselves to carry out familiar and repetitive mental activities, routines requiring no application effort or acquisition of new skills. This kind of activity is not sufficient to keep the brain fully functioning: if we stop learning new things, we are destined to ageing brain.

- **“Noisy” processes.** In old people brain sensory deterioration causes noise; for example, in hearing loss the sound signals sent to the brain are more confused and difficult to interpret. Therefore the brain must slow its activities to decipher confused signals, so mental representations are incomplete. This causes a poorer memory and less elastic thinking skills.

- **Weakening of neuromodulatory function.** In elderly age the brain produces fewer neurotransmitters, chemicals like dopamine and acetylcholine, which play an essential role in learning and memory.

- **Negative learning.** People who begin to feel less mentally agile than once tend to implement mechanisms for compensation. If, for example, their hearing is impaired, they turn off the TV, or learn to read words on the lips (Merzenich, 2005).

Merzenich has identified a number of strategies to overcome these problems:

- To combat disuse: engage the brain in new challenging tasks;
- To help the brain to order confusing signals: carry out activities that require attention and concentration;
- To regulate the production of neuromodulators: activities able to activate their production;
- To eliminate compensatory adaptive behaviors: engaging in activities that have become complicated to perform, rather than avoid them.

The most effective activities are those in which is required to distinguish between what one hears, sees and feels and use this information to achieve goals more and more difficult.

6. New learning and teaching strategies to address the challenge of adult education

Learning in mature age seems to be the most problematic: senile involution related to brain tissues’ ageing causes a loss of efficiency of the mind that progresses with age and that makes it even more complex the design and implementation of training programs tailored to the characteristics of older learners. The researches in neuroplasticity confirm that learning in adult and mature age can be successful if we engage our brain in new challenging tasks, dealing with complex and problematic activities. Learning depends completely on the existence of neuroplasticity: it allows new information to be retained, represented and processed. The challenge the adult education is called to meet is to transform old pedagogic models, rethinking adult learning in a perspective of flexibility and personalization reflecting the increasing complexity and fluidity of real world (Wil-
by its holistic nature, problem-centered, contextualized and personalized approach to education. The recent studies in adult education and gerontology field highlight how learning in mature age is characterized by its holistic nature, problem-centered, contextualized and personalized (Guglielman, 2004; Guglielman et al., 2005).

Adult learning experience should be developed taking into account learner’s priorities, motivation, learning needs, learning request, previous knowledge, previous learning experiences, previous competences, and potential areas of development; the learning effort should be oriented towards an experience focused on themes and problems significantly connected to real life, useful and usable in daily practice. In this perspective a course need to be focused on themes and problems instead of contents and disciplines; it needs to adopt a situational approach instead of theoretical approach; it should include concrete tasks; it should indicate a usable application also referable to daily life.

Moreover, should be proposed strategies and activities that exploit the principles of neuroplasticity to improve cognitive function and ensure that education in old age is an enjoyable, rewarding and effective experience. First of all it is necessary to change a consolidated mental attitudes about learning and about teaching, taking in mind the complexity of new hybrid, ubiquitous and liquid learning scenarios. The Scaffolding Theory of Ageing and Cognition (STAC) postulates that changes with ageing are a part of a process of compensatory cognitive scaffolding aiming to alleviate the cognitive decline of ageing. This process is fostered by cognitive engagement, exercises, new learning and consists in the recruitment of additional brain circuits supporting declining structures that has become noisy or inefficient (Park & Reuter-Lorenz, 2009; Park & Bischof, 2011).

Older foundations of thought were based on a linear stage development concept. The paradigm of connectivism, that considers learning as a process of building nets and connections, appears particularly close to this vision: according to this theory, knowledge is chaotic, complex and holistic, reticular and not linear (Siemens, 2004, 2006). Our life experience reflects the net system of interconnections; knowledge assumes the contours of a volatile changeable, dialogic entity rather than the form of a stable, structured and organized system. The application of connectivism-based learning strategies requires the reversal of traditional learning patterns. The first students’ reaction is generally of defence, rejection and cognitive dissonance, caused by the habit to live the educative process as relegated in a structured and “protected” environment. This dissonance represents a first indicator of the beginning of a change for the learner; this is the first step to make an effort carrying out stimulating and not repetitive tasks, and the opportunity to fight the brain disuse.

One innovative educational model able to meet this challenge is Complex Learning (McDonald, 2005; Rohse, Anderson, 2006; Van Merriënboer, Clark & de Croock, 2002); under this term we can recognize various visions and interpretations, referring to common principles but realizing practices in different ways (Ferri, 2003). In this model is clearly recognizable the reconfiguration among several didactic means and tools, the emergence of new nexuses and hierarchies among media, the appearance of new languages and new interaction modalities. In Complex Learning the term “complex” refers to the problematic nature of reality and, consequently, of knowledge: learning is, in fact, a complex activity. According to complexity and chaos theories, human cognition can be viewed as a complex system, that interacts with its environment and can be modified by it; traditional approaches often don’t adequately address the complex and multi-dimensional nature of cognition. The learning experience is not limited in the course boundaries: learner interacts not only with his peers and with the course staff, but also with domain experts, key actors, stakeholders, individuals and communities sharing his interests at both formal and informal level (Guspini, 2008; Guglielman & Vettraino, 2009).

The integration among different educational procedures, communication tools and technologies contributes to develop and improve learning in the age of knowledge, generating value and competitiveness. The chance to create a customized environment deeply changes the way we learn: the structure of a learning environment, in fact, directs the student to certain learning schemes, fostering from time to time dynamics linked to the space design and its features (Goodyear, 2001). Active involvement of the student in designing and building his space represents an innovation compared to models that offer prearranged learning environments.
7. Conclusions

The recent progresses in neuroscience demonstrate that learning is not confined only to younger generations and to persons with a mindat full capacity, but that it can be implemented in all stages of life with equal effectiveness; and, most important, that a continuous learning activity contributes to increase neuronal regeneration and to avoid the effects of ageing.

A specific mental training can improve motor and sensory representations in the cortex, fostering the signal transmission restitute effectiveness to the neuronal connections. An uninterrupted and constant mental activity constitutes an important factor in delaying the arise of neurodegenerative diseases like Alzheimer’s. A deeper understanding of the brain appears highly relevant to education: understanding how the brain works in the elderly can help us in developing methods of teaching and learning more effective and appropriate for different ages and to keep people active throughout life (Lovat et al., 2011; Willis, Schaie & Martin, 2009; Greenwood & Parasuraman, 2012).

The static model of the brain based on the idea of irreversible neuronal decay has been for a long time the basis of the prejudice that elderly people are unable to learn new things. Neuroscientific researches demonstrate that specific sets of activities and exercises designed to stimulate new neural connections and reorganize cortical maps allow to make successfull and rewarding elderly learning. Now we know that learning is ageless: it is a cumulative process that continues throughout life. Even if the way of learning diversify and change with age, the ability to learn remains (Tyler John, 1988).

According to Goswami, “Biological, sensory and neurological influences on learning must become equal partners with social, emotional and cultural influences if we are to have a truly effective discipline of education” (Goswami, 2008). The application of neuroscience theories about brain plasticity to adult education is therefore essential to promote lifelong learning through the creation of learning environments based on competences, situated learning and active construction of knowledge.

References


Commission of the European Communities (2006). Adult learning: it is never too late to learn, Brussels.


In-depth


Edition and production
Name of the publication: eLearning Papers
ISSN: 1887-1542
Publisher: elearningeuropa.info
Edited by: P.A.U. Education, S.L.
Postal address: c/Muntaner 262, 3r, 08021 Barcelona (Spain)
Phone: +34 933 670 400
Email: editorial@elearningeuropa.info
Internet: www.elearningpapers.eu

Copyrights
The texts published in this journal, unless otherwise indicated, are subject to a Creative Commons Attribution-Noncommercial-NoDerivativeWorks 3.0 Unported licence. They may be copied, distributed and broadcast provided that the author and the e-journal that publishes them, eLearning Papers, are cited. Commercial use and derivative works are not permitted. The full licence can be consulted on http://creativecommons.org/licenses/by-nc-nd/3.0/