Maria Montessori and Neuroscience: the Trailblazing Insights of an Exceptional Mind

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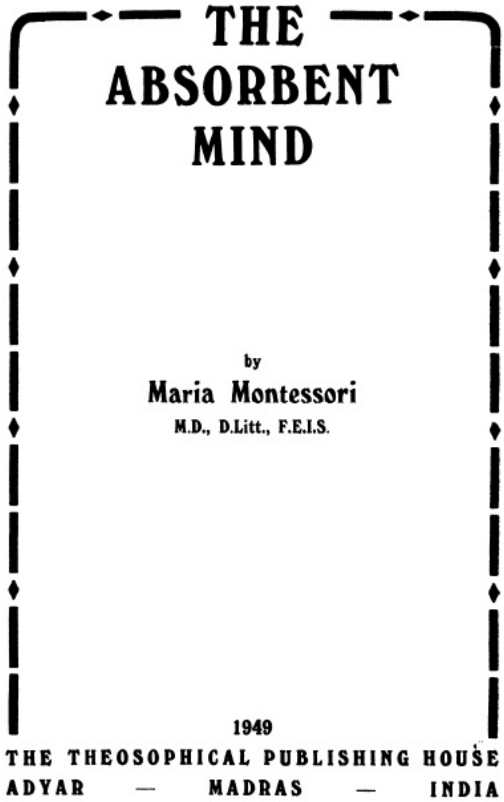
Maria Montessori (1870-1952), one of the most original and influential scholars of the 20th century, is best known for her revolutionary child-centred method of education, which is still used in schools throughout the world. Freud, the father of psychoanalysis, told her: "If everyone had your schools, they wouldn't need me". However, her educational philosophy – which was rooted in her lifelong observation of children – was based on a number of strikingly accurate hypotheses on child development which predated several neuroscientific discoveries by decades (Babini and Lama, 2016).

Montessori was born in Chiaravalle, a village in Marche (Central Italy), to a middle-class Catholic family. In 1896 she took a medical degree at the university of Rome, becoming one of the first women in Europe to practice medicine. An early experience with children with mental disabilities living in Rome's asylums proved critical for the development of her educational philosophy and method, which she devised to teach all children. The method is based on self-education, freedom, activity, movement, and practical experience. She posited that children should be surrounded by simple objects in different shapes which can be manipulated and variously combined, in–rooms with specially designed small furniture. Within 10 years of its publication, in 1909, the book where she first described her method was translated into 36 languages and printed in 58 countries.

Montessori became an international personality and an advocate for women's and children's rights. In 1934 she fled to Spain to escape fascism, but in 1936 she had to move again due to the civil war. From 1939 to 1946 she lived in India, where she continued to study and teach. Her Indian lectures constitute the bulk of *The absorbent mind* (Montessori, 1949), the latest and most comprehensive presentation of her thinking. Her theory integrates the insights of the physician and the educator, combining biological notions with the effects of the environment. Her observations of children led her to advance a revolutionary theory of education that touched on most aspects of child development. Even more remarkably, several of the insights on which her child-centred educational method rests predated several major neuroscientific discoveries by decades. Some of the pioneering hypotheses on which she based her educational theory are summarized below.



THE
ABSORBENT
MIND

by
Maria Montessori
M.D., D.Litt., F.E.I.S.

1949
THE THEOSOPHICAL PUBLISHING HOUSE
ADYAR — MADRAS — INDIA

Figure 1

Montessori identified three **critical periods in children's psychobiological development**. In her view, the child is a *spiritual embryo,* whose psychological development and biological growth proceed together through *sensitive periods*, in which the child is interested in and receptive to certain domains and acquires a number of specific skill and abilities. These three phases go from birth to 6 years, from 7 to 11 years, and from 12 to 18 years, the latter period involving such momentous transformations as to be reminiscent of the first.

Neuroscientific work supporting these observations began to be published in the 1960s, showing that in early childhood the cat and monkey brain is highly plastic and is strongly influenced by the environment (Hubel and Wiesel, 1962, 1070; Wiesel and Hubel, 1963). This line of research eventually led to the award of the 1981 Nobel prize in Physiology or Medicine to Hubel and Wiesel. Montessori's tenet that adolescence is a period of deep transformations has also been confirmed by studies showing that the adolescent brain undergoes profound changes – more in terms of connectivity than of neural growth – until 18-20 years, when it reaches its adult structure and function (Giorgio and others, 2008).

A ground-breaking notion in Montessori's thinking was the crucial **importance of the environment in supporting neural/cerebral development and in promoting learning**, also through motivation.

Scientific confirmation for it came from animal studies demonstrating that a rich and varied physical and relational environment affects the cerebral microenvironment and can even extend the critical period of brain plasticity into adulthood (Hensch, 2004; Di Garbo and others, 2011; Tognini and others, 2012), enhancing cognitive ability and even the synaptic plasticity of the visual cortex (Sale and others, 2009), and reinforcing the connections and information exchanges between cortical areas.

Another factor whose significance Montessori perceptively recognized was the **powerful influence of affective stimulation on psychological growth and maturation**.

Her intuition has eventually been substantiated by a wide range of studies. For instance, the description of Spitz syndrome – which is caused by sensory deprivation – in 1945 eventually led to the identification of anaclytical depression in children divided from their caregivers: all symptoms disappear when the child is reunited to the mother/caregiver. As regards the neural mechanism involved in the beneficial effects of affective stimulation on nervous system development, a seminal study showed that rat pups raised by a "good mother" – one which spends time licking and grooming them – will be healthier and more resistant to stress as adults, through a higher expression of hippocampal glucocorticoid receptor (Zhang and others, 2010; McGowan and others, 2011).

Montessori's observations also suggested to her that humans possess **a neural structure that specifically enables the acquisition of a language**, the actual language being determined by the environment.

Scientific evidence for this view came from the work, among others, of Noam Chomsky, who since 1957 developed his theory that language abilities are rooted in neural (cortical) brain structures and in a species-specific computational ability (Chomsky, 1981). These skills have identifiable correlates in the brain and have not changed since the origin of language about 100,000 years ago (Berwick and others, 2013). Although songbirds share with humans an ability to learn vocal imitation and a similar underlying neural organization, language is uniquely human.

Another striking insight was the vital **role of fine object manipulation in neuropsychological development,** which led Montessori to state that "the hand is the organ of the brain" (Montessori, 1949).

Figure 2

This intuition has duly been confirmed, too. Brain mapping studies have demonstrated that the size of the motor and sensory cortical regions devoted to the representation of the hand exceeds even the dimension of the hand itself, indicating that a huge number of neurons are involved in controlling its movements and in processing its sensory information. Interestingly, in string players the left hand representation is much larger than in other individuals (Elbert and others, 1995), the reorganization being more pronounced in those who began playing earlier (Wilson, 2010). Such high sensory resolution of the information coming from the tactile receptors of the hand makes it possible, among other things, to read Braille. Hand movements are so important that their limitation may also have dramatic effects. The finding that children who have been using a tablet since early infancy have delayed language development (https://www.repubblica.it/tecnologia/2014/05/03/news/ricerca_tablet_e_smartphone_ritardano_apprendimento_bambini-85130135/?ref=search) has led scientists to recommend avoiding touchscreen devices until 2 years of age, and to allow them sparingly afterwards (Radesky and others, 2016). Critically, hand motor activity may help to think and influences problem-solving, enhancing overall or systemic working memory resources if the activity is simultaneous with the intellectual task (Vallée-Tourangeau and others, 2016a, 2016b).

However, Montessori’s most remarkable intuition is, in our view, the **central role played by physical exercise in brain and nervous system development**. Based on the trivial fact that the muscles account for about 30% of body weight, Montessori inferred that exercise must have a significance that went beyond mere body fitness and gave it a prominent role in children’s daily activities.

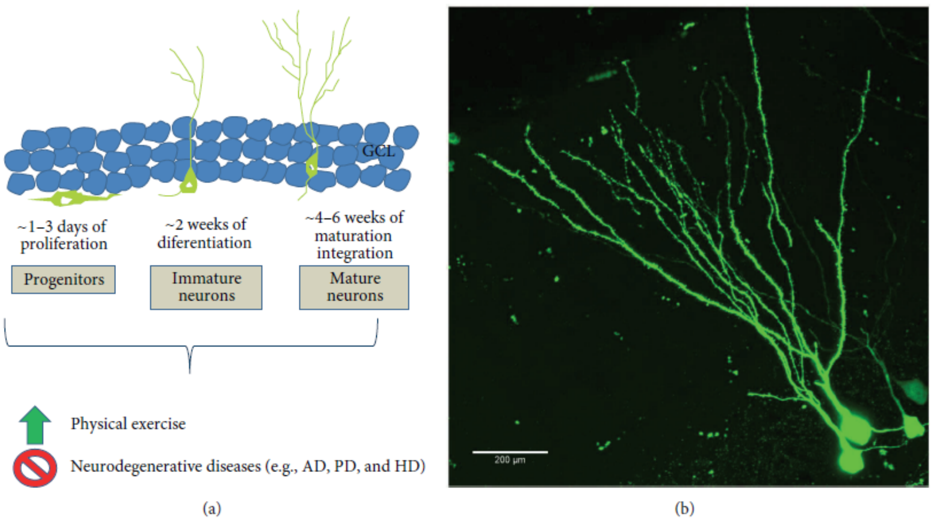


FIGURE 1: Development and integration of adult-born neurons in the dentate gyrus of the hippocampus. (a) The neural progenitors that are divided from neural stem cells start expressing either neuronal or glial phenotypes after just a few days of division. Newborn neurons gradually migrate from the subgranular zone (SGZ) into the granular cell layer (GCL) where they undergo maturation, followed by functional integration into the existing neural circuitry in the hippocampus. This process of hippocampal neurogenesis is known to be promoted by physical exercise and to be compromised in several neurodegenerative diseases such as AD, PD, and HD. (b) Confocal image of 4-week-old retroviral-labeled newborn neurons with green fluorescence protein (GFP) in the GCL (scale bar: 200 μm).

Figure 3

The view that exercise is a critical factor enhancing brain development continues to receive confirmation, so much so that the motor system has come to be included in the cognitive system. Accordingly, aerobics and other types of exercise have been found to stimulate neurogenesis, also in adults and in the elderly, and to improve fibre myelination (Erickson and others, 2013; Gons and others, 2013; **Yau and others, 2014**; Pedersen, 2019). Regular exercise enhances cerebral functions by increasing cognitive ability, memory, general plasticity, and grey matter volume besides improving mood. Physical activity stimulates the production of neural (brain-derived neurotrophic factor) and glial (glial-derived neurotrophic factor) growth factors by the brain (Pedersen, 2019); it induces faster recovery from cerebrovascular accidents (stroke); it delays the onset of neurodegenerative disorders (Alzheimer's disease, multiple sclerosis, dementia; **Yau and others, 2014**) and can improve the control of the motor symptoms of Parkinson's disease (Pepper, 2011). Notably, a 15-year-old who was diagnosed with dyspraxia at age 5 years took up sports and achieved such marked improvement in his symptoms that he went on to win athletic competitions (http://www.athletics.org.nz/News/guthrie-crofts-triple-treat). Last but not least, physical activity seems to help prevent cancer development and enhances the effect of treatment, so that 30 minutes of exercise have been included in cancer patients' daily regimens (http://www.repubblica.it/oncologia/qualita-di-vita/2017/02/10/news/cura_dei_tumori_attivita_fisica_come_terapia-157999087).

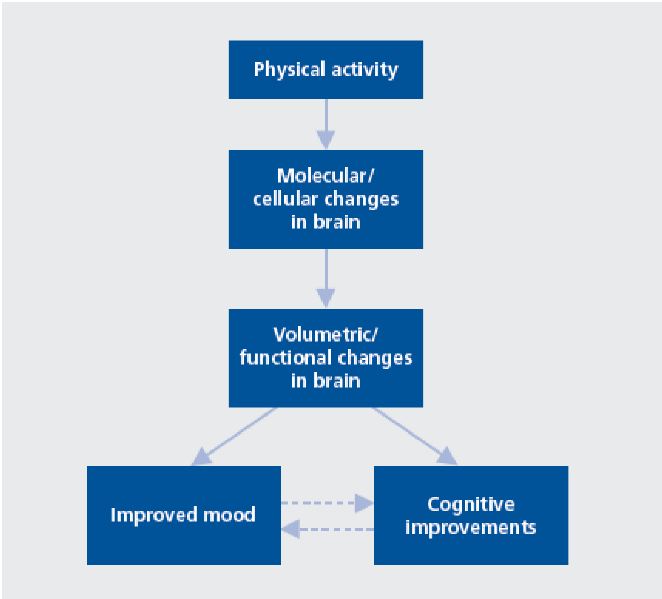


Figure 1. A schematic representation of the general path by which cognitive function and mood are improved by physical activity. It could be hypothesized that improvements in cognitive function mediate the improvements in mood or that improvements in mood mediate some of the improvements in cognitive function. The dotted lines represent these hypothesized paths.

Figure 4

Maria Montessori, who resolutely pursued her own education in the face of considerable difficulties and opposition and sacrificed important areas of her life to her research, was an exceptional scholar and educator whose insights predated a surprising number of crucial medical discoveries.

To celebrate the genius of this famous daughter of the Marche region, the local Medical School has named its impressive Auditorium for Maria Montessori.

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