International Journal of Prenatal & Life Sciences
in search of meaning
ISSN: 2945-011X
DOI: 10.24946/IJPLS
WOMBING PEACE

Publication date: 27 February, 2023
DOI: 10.24946/IJPLS/2023.07.03

The importance of prenatal and postnatal stimulation

AUTHORS: Milica Ćirović[1,2], Dorotea Janić[1,2], Ljiljana Jeličić[1,2]
Communication Author: Milica Cirovic

[1]Cognitive Neuroscience Department, Research and Development Institute "Life Activities Advancement Institute", Belgrade 11000, Serbia; m.cirovic@add-for-life.com (M.C); d.janic@add-for-life.com (D.J.); lj.jelicic@add-for-life.com (Lj.J.)
[2]Department of Speech, Language and Hearing Sciences, Institute for Experimental Phonetics and Speech Pathology, Belgrade 11000, Serbia

Abstract: Certain stimulations in the prenatal and early postnatal period may have irreversible effects on later stages of human cognitive and emotional maturity. The period between conception and birth, and the first thousand days of life are the critical periods for establishing the basic foundations for child development. Recent research showed that the fetal auditory cortex becomes mature in the third trimester of pregnancy, indicating functional fetal hearing in this period. On the other hand, there are research findings indicating to which extent prenatal and early postnatal stimulation may improve cognitive and sensory-motor development, prevent deprivation, and even epigenetic widen the limits of human perception. The paper discusses the role of prenatal auditory development in child development, and also highlighted the positive effects of prenatal and early postnatal stimulation in the improvement of child psychophysiological capacity. In that sense, the paper points to the importance of prenatal and postnatal stimulation which may lead to healthy fetal and child development.

Key words: prenatal auditory development, auditory stimulation, prenatal stimulation, child development

Introduction

In recent decades, authors emphasise the importance of prenatal and early postnatal stimulation as an important factor for healthy fetal and later on, child development. Due to the brain plasticity that characterizes the period of children's early development, the term prenatal learning is increasingly used instead of the term prenatal stimulation. The adequacy of this term is reflected in the fact that different types of prenatal and early postnatal stimulation enable easier adaptation of the newborn life outside the womb.

It is known that during intrauterine life, a fetus is most exposed to auditory stimulation. Also, the cochlea, the part of the inner ear, becomes functional before its maturation at 35 weeks of gestation (1), allowing the fetus to perceive different auditory stimulation. For this reason, a large number of studies emphasize the importance of prenatal auditory stimulation for developing an ability to distinguish mothers' voices from other sounds (2,3) or mothers' native language over other unfamiliar languages (4) in infants.

This paper discusses the role of prenatal and early postnatal auditory stimulation in child development and highlights its benefits that are reflected in the reviewed literature.

A definition of a sensitive period in child development

The sensitive period is the developing learning mechanism that influences the development of cognition and perception in a certain time frame during early development. During this time frame, various environmental stimuli are encoded to stimulate adaptive development (5). Heightened brain plasticity during a sensitive period allows quick reactions of the nervous system to different stimuli. Due to the action of various external stimuli, the sensitive period shapes the response of the nervous system according to the type of stimuli (6). The beginning of the sensitive period is defined by biological and empirical factors and it is regulated by molecular triggers and pacers that increase neuroplasticity. The physiology of the sensitive period is very complex but it is known that it is based on the elimination of a vast number of neurons and synapses to make neurological patterns as a response to environmental stimuli. After the sensitive period is over the changes in brain structure are minor. Also, experiences that failed to occur during sensitive periods cannot make brain changes if occur later in life, implicating that brain plasticity declines during a lifetime.

Sensitive and critical periods: the difference and characteristics

The difference between sensitive and critical periods has been studied in naturally deprived infants (7). Skill development in humans is ordered: the development of a complex skill is conditioned by the development of a less complex skill (8). This means that delay of the sensitive period for one function will delay the beginning of the sensitive period for the subsequent function, implying that sensitive periods are codependent and interconnected (9). On the other hand, the critical period refers to the time frame when a specific ability can be developed. During the critical period for exerting testicular hormones, the changes in a number of nuclei or in the structure are made in the hypothalamus, spinal cord, visual cortex, and hippocampus (10). On the other hand, if a certain developmental process doesn't occur in a critical period, it makes permanent developmental consequences. For example, thyroid insufficiency in the prenatal critical period causes iodine deficiency which can cause mental ratardation (11).

Critical periods determine if and what consequences will early lesions have on early development: lesions of the left brain hemisphere before age one affect verbal and performance IQ, while lesions formed after the age of one do not affect IQ. On the other hand, similar lesions of the right brain hemisphere before and after the age of one affect performance IQ (12). Further, early prenatal lesions of the rostromedial and orbitomedial frontal cortex have negative consequences such as maladaptive and inappropriate social behavior (13).

The early postnatal period is considered to be a critical period for socialization in humans. During this period, social deprivation leads to incapacity to develop adequate social interaction and communication, mental illnesses, or a weak immune system (14).

Understanding critical periods have benefited the treatment of congenital deafness. The positive effects of implementation can be seen only in children who were implemented before age of three (15); implementation after the age of three results in poor language and complex auditory understanding (16, 17).

Executive functions differ from other developmental abilities due to the fact that plasticity lasts the longest for them because they continue to develop in adulthood. There is not one critical period for executive functions because they consist of more than one function. Some of these functions have their own critical periods and some do not (18). It is known that a deficit in executive functions can be

caused by cognitive deprivation often seen in neglected children (19,20). This data can provide us insight into the developmental mechanisms of executive functions.

By understanding the role of neural plasticity in prenatal and early postnatal development, we can better understand the importance of early stimulation. Prenatal or early postnatal stimulations are tightly connected with brain plasticity meaning that adequate stimulation can make permanent functional changes in an infant's brain influencing its further development.

A sensitive period for speech and language development

Auditory and language development are tightly connected. The human auditory system becomes functional around the 7th month of pregnancy (21), but some parts of the auditory system, such as the cochlea, start to perform their function in auditory transduction at the 24th GA (22). Papers that study prenatal auditory development showed that fetuses start to react to external sounds around the 24th GA with agitation (23) and around the 28th GA on loud tones with increased heart rate (24). These findings could be explained by the fact that all external sounds and sounds that are produced by a mother like her speaking, singing, coughing or even bowl movements are conducted to the womb through the mother's muscles, so that fetus is exposed to the sounds from the moment of the conception. This implies that the auditory cortex becomes active even during intrauterine development. Knowing that language development is conditioned by auditory development, it is right to conclude that postnatal development of speech and language is determined by prenatal sound perception.

Sensitive periods for auditory and language development in the postnatal period were observed in congenitally deaf newborns and a few cases of "wild children". Congenitally deaf children develop nonverbal communication like gestures and sign language. Petitto et al., study shows that the language system is activated in the same way in deaf people while presented with sign language as in hearing people while hearing speech (25). This founding can be explained by the fact that human speech has two components: auditory and visual, meaning that while we listen to the speaker, we "read" his facial expressions and body movements. Further, in congenitally deaf people, the visual brain areas, instead of the auditory brain areas, are synapsed with language cortical areas, allowing them to "hear" sign language.

On the other hand, cases of "wild children" show that although the auditory system is adequately developed, the lack of language stimulation leaves permanent consequences on the language system, showing that language development is conditioned by a child's experiences.

For this reason, it is considered that the critical period for language acquisition is in the first seven years of a child's life. This can be observed in the process of learning a second language: grammar and pronunciation can be mastered as in native speaker only if the second language is learned by the age of seven; if the process of learning starts after the age of seven grammar can never be fully mastered (26).

Early stimulation: The positive effect on a child's psychophysiological development

Sensitive periods in child development are characterized by forming a vast number of neurons and synapses. The adequate stimulation creates new synapsis and neurological paths and frequent use of these newly created paths established them. On the other hand, unused paths are eliminated in the process of pruning. Not only in the postnatal, but even during the prenatal period, the fetus is exposed to different kinds of stimuli like auditory, tactile and vestibular. Tactile stimuli that a fetus can experience are caused by the mother's speech, laughter, heartbeat, and breathing because of the muscles' contraction during the production of these sounds (27). Also, fetal movements are conditioned by proprioceptive information and alterations in skin pressure (28). On the other hand, premature infants are deprived of sensory stimulation compared to full-term infants in terms of the amount and type of stimuli. These infants lack prenatal tactile and vestibular stimulation, and on the other hand, they are exposed too early to visual and auditory stimulation. All these factors contribute to altered patterns of visual, auditory, olfactory, vestibular, and proprioceptive stimulation in

premature infants (29). These inadequate stimulations can cause negative consequences to cognitive and perceptual development leaving permanent brain damage (30, 31).

In the early postnatal period newborns, systematically learn how to integrate various stimuli coming from divergent sensory systems (32). This process of learning takes place during a newborn's interaction with an object. During the interaction, various information is perceived through different sensory systems that gradually start to integrate. This process of integration allows a synthesized perception of objects and events (33).

It is known that sensory stimulation has an important part in cognitive development, sensory development, and the development of selective attention (34). Also, prenatal sensory stimulation has a key role in perceptual and cognitive development (35, 36, 37). Knowing this, the stimulation of all five senses in a highly stimulative environment is crucial for developing newborns' full potential. Studies show that auditory prenatal stimulation like listening to a mother's voice or listening to the same piano melody can develop a sense of a safe and unsafe environment in infants (38) or fasten heart rate as a result of the recognition of the familiar melody (39). The results of these studies are showing that prenatal stimulation has undoubted effects on fetal development. It is still unknown how long prenatal stimulation should last in order to have permanent effects but it is undoubtedly that prenatal stimulation benefits the child's development in both prenatal and postnatal periods.

Authors' note: MĆ and LJ are working member of COST Action CA18211: DEVoTION: Perinatal Mental Health and Birth-Related Trauma: Maximizing best practice and optimal outcomes. This paper contributes to the EU COST Action 18211: DEVoTION.

Funding: This work was partially supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia within the project "Influence of psychophysiological, sociological, and cultural factors on speech and language in the child population". This project is realized in cooperation with the Faculty of Medical Sciences, University of Kragujevac, Serbia.

References

1. Morlet T, Collet L, Salle B, Morgon A. Functional maturation of cochlear active mechanisms and of the medial olivocochlear system in humans. Acta Otolaryngol. 1993;113(3):271-277.
2. Kisilevsky BS, Hains SM, Lee K, Xie X, Huang H, Ye HH, et al. Effects of experience on fetal voice recognition. Psychol Sci. 2003;14(3):220-224.
3. Smith LS, Dmochowski PA, Muir DW, Kisilevsky BS. Estimated cardiac vagal tone predicts fetal responses to mother's and stranger's voices. Dev Psychobiol. 2007;49(5):543-547.
4. Bertoncini J, Bijeljac-Babic R, Jusczyk PW, Kennedy LJ, Mehler J. An investigation of young infants' perceptual representations of speech sounds. J Exp Psychol Gen. 1988;117(1):21.
5. Greenough WT, Black JE, Wallace CS. Experience and brain development. 2002.
6. Takesian AE, Hensch TK. Balancing plasticity/stability across brain development. Prog Brain Res. 2013;207:3-34.
7. Nelson CA III, Zeanah CH, Fox NA. How early experience shapes human development: the case of psychosocial deprivation. Neural Plast. 2019.
8. Cicchetti D, Handley ED. Child maltreatment and the development of substance use and disorder. Neurobiol Stress. 2019;10:100144.
9. Fagiolini M, Pizzorusso T, Berardi N, Domenici L, Maffei L. Functional postnatal development of the rat primary visual cortex and the role of visual experience: dark rearing and monocular deprivation. Vision Res. 1994;34(6):709-720.
10. Kandel ER, Schwartz JH, Jessell TM, Siegelbaum S, Hudspeth AJ, Mack S, et al. Principles of neural science. Vol 4. McGraw-hill; 2000. p. 1227-1246.

11. Kooistra L, Laane C, Vulsma T, Schellekens JM, van der Meere JJ, Kalverboer AF. Motor and cognitive development in children with congenital hypothyroidism: a long-term evaluation of the effects of neonatal treatment. J Pediatr. 1994;124(6):903-909.
12. Tranel D, Damasio H, Denburg NL, Bechara A. Does gender play a role in functional asymmetry of ventromedial prefrontal cortex? Brain. 2005;128(12):2872-2881.
13. Anderson SW, Bechara A, Damasio H, Tranel D, Damasio AR. Impairment of social and moral behavior related to early damage in human prefrontal cortex. Nat Neurosci. 1999;2(11):1032-1037.
14. Spitz RA. Hospitalism: A follow-up report on investigation described in Volume I, 1945. Psychoanal Study Child. 1946;2(1):113-117.
15. Niparko JK, Tobey EA, Thal DJ, Eisenberg LS, Wang NY, Quittner AL, et al. Spoken language development in children following cochlear implantation. JAMA. 2010;303(15):1498-1506
16. Tong YC, Busby PA, Clark GM. Perceptual studies on cochlear implant patients with early onset of profound hearing impairment prior to normal development of auditory, speech, and language skills. J Acoust Soc Am. 1988;84(3):951-962.
17. Busby PA, Tong YC, Clark GM. Psychophysical studies using a multiple-electrode cochlear implant in patients who were deafened early in life. Audiology. 1992;31(2):95-111.
18. Zelazo PD, Anderson JE, Richler J, Wallner-Allen K, Beaumont JL, Weintraub S. II. NIH Toolbox Cognition Battery (CB): Measuring executive function and attention. Monogr Soc Res Child Dev. 2013;78(4):16-33.
19. Lambert HK, King KM, Monahan KC, McLaughlin KA. Differential associations of threat and deprivation with emotion regulation and cognitive control in adolescence. Dev Psychopathol. 2017;29(3):929-940.
20. Sheridan MA, Peverill M, Finn AS, McLaughlin KA. Dimensions of childhood adversity have distinct associations with neural systems underlying executive functioning. Dev Psychopathol. 2017;29(5):1777-1794.
21. Moon C. The role of early auditory development in attachment and communication. Clin Perinatol. 2011;38(4):657-669.
22. Pujol RMM, Lavigne-Rebillard M, Lenoir M. Development of sensory and neural structures in the mammalian cochlea. In: Romand R, Varela-Nieto I, eds. Development of the Auditory System. Springer; 1998:146-192.
23. Lecanuet JP, Schaal B. Fetal sensory competencies. Eur J Obstet Gynecol Reprod Biol. 1996;68:1-23.
24. Moore JK, Guan YL. Cytoarchitectural and axonal maturation in human auditory cortex. J Assoc Res Otolaryngol. 2001;2(4):297-311.
25. Petitto LA, Zatorre RJ, Gauna K, Nikelski EJ, Dostie D, Evans AC. Speech-like cerebral activity in profoundly deaf people processing signed languages: implications for the neural basis of human language. Proc Natl Acad Sci USA. 2000;97(25):13961-13966.
26. Johnson JS, Newport EL. Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. Cogn Psychol. 1989;21(1):60-99.
27. DeCasper AJ, Fifer WP. Of human bonding: Newborns prefer their mothers' voices. Science. 1980;208(4448):1174-1176.
28. Robertson SS, Bacher LF. Oscillation and chaos in fetal motor activity.
29. Lickliter R. The role of sensory stimulation in perinatal development: insights from comparative research for care of the high-risk infant. J Dev Behav Pediatr. 2000;21(6):430-441.

30. Als H. NIDCAP: testing the effectiveness of a relationship-based comprehensive intervention. Pediatrics. 2009;124(4):1208-1210.
31. Gressens P, Rogido M, Paindaveine B, Sola A. The impact of neonatal intensive care practices on the developing brain. J Pediatr. 2002;140(6):646-653.
32. Birch HG, Lefford A. Intersensory development in children. Monogr Soc Res Child Dev. 1963;28(3):1-48.
33. Freides D. Human information processing and sensory modality: cross-modal functions, information complexity, memory, and deficit. Psychol Bull. 1974;81(5):284.
34. Lickliter R, Bahrick LE. The development of infant intersensory perception: advantages of a comparative convergent-operations approach. Psychol Bull. 2000;126(2):260.
35. Foreman N, Altaha M. The development of exploration and spontaneous alternation in hooded rat pups: Effects of unusually early eyelid opening. Dev Psychobiol. 1991;24(7):521-537.
36. Gottlieb G. Ontogenesis of sensory function in birds and mammals. The biopsychology of development. Academic Press; 1971. p. 67-128.
37. Gottlieb G. Conceptions of prenatal development: behavioral embryology. Psychol Rev. 1976;83(3):215.
38. Huotilainen M. Building blocks of fetal cognition: emotion and language. Infant Child Dev. 2010;19(1):94-98.
39. Granier-Deferre C, Bassereau S, Ribeiro A, Jacquet AY, DeCasper AJ. A melodic contour repeatedly experienced by human near-term fetuses elicits a profound cardiac reaction one month after birth. PLoS One. 2011;6(2):e17304.