Wagner for the Womb

By Rosalind Lai

Does pre-natal music stimulation affect the intelligence of a fetus? Scientists are understanding whether music affects brain development early on before birth.

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MUSIC, INTELLIGENCE, AND BABIES – CAN WE LINK THESE TOGETHER?

MUSIC SINCE THE BEGINNING OF TIME

As humans, we all share one unique feature – the ability to produce and enjoy music. Music is not a new concept though. More than 165,000 years ago, our ancestors have already invented percussion instruments. Today, all societies and cultures have music. With these ancient roots, music undoubtedly plays a significant part in our lives today. Over the past ten years, a record number of 297 million Apple IPods alone have been sold around the world. There are reasons for our fondness for music.

Music affects our emotions and activates certain brain areas, the same centers of the brain for food and drug addictions. It seems that our appreciation for music is innate. Infants, even as young as two months old, turn to pleasant sounds, but away from dissonant, harsh, sounds. This fascination of music has made many scientists ponder – does music affect more than our emotions? Does music physically change the brain and affects our intelligence?

distinguish the mother's voice from others. Since sound plays a role in the development of the fetus in the womb, a central question has arised - does music affect fetal development?

RESEARCH IN ANIMAL MODELS

Since it is difficult, unethical and impractical to perform studies on human fetus, much research has been concentrated on the animal model. Whether animals have the same appreciation for music is debatable, but a few studies have found an effect on pre-natal auditory stimulation.

One study looked at whether pre-natal auditory stimulation affects spatial memory in rats. The researchers exposed pregnant mothers to noise or music for an hour a day until delivery and tested the pubs' navigational ability in a maze test after birth. They found that the group stimulated with pre-natal music took much less time to find food in a maze compared with the group with no stimulus or the

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THE MOZART EFFECT

Perhaps one of the most well-known and arguably most controversial phenomena is the Mozart Effect. The term was first coined by Dr. Afred Tomatis, who suggested that listening to compositions of Mozart increases a child's IQ. This idea has been so favorable and popularized that the Governor of Georgia, Zell Miller, even proposed a budget to provide all children in Georgia with a CD of classical music. However, there has been great controversy among the scientific community as numerous studies have failed to replicate this finding.

Whether music improves intelligence in children remains to be elucidated. However, a new area of research is not studying music in childhood, but music in the womb. At late gestational stage, the fetus can hear sounds from outside the mother, and from these sounds, can become familiarize to her voice. After birth, the infant can

group stimulated with random noise. Interestingly, the group stimulated with random noise performed even worse than the unstimulated group, suggesting it is music, and not random noise, which contributed to the improvement in spatial memory.

Similar studies in different animal models have been replicated to correlate prenatal music stimulation with enhancement of spatial learning. In another study, music or no stimulation was provided to fertilized chick eggs. Following hatching, the chicks were trained to perform a similar maze task to test for memory. The researchers found that music-stimulated chicks took less time to reach the target compared with the un-stimulated group. These studies, taken together, suggest that pre-natal auditory stimulation does have an effect on learning, at least in the animal model. However, what is the underlying mechanism for these enhancements, and are these changes due to the brain being structurally altered?

NEW NEURONS IN MEMORY CENTER OF THE BRAIN

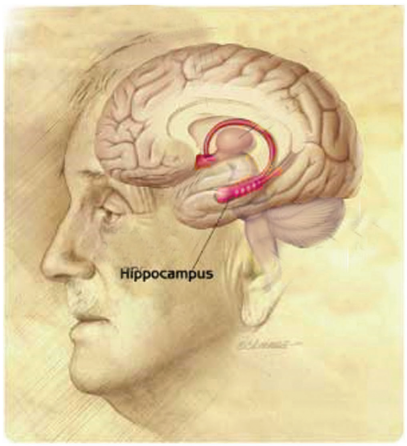
Numerous studies have found that pre-natal exposure to music in the animal model increases neurogenesis, the birth of neurons, in the memory-center of the brain, the hippocampus. The hippocampus is a major brain structure present in all mammals involved in the consolidation of short-term to long-term memory, and in spatial navigation. Damages to this area of the brain result in memory loss. Alzheimer's disease is an example where the loss of memory is largely attributed to damages at the hippocampus.

On the contrary, studies have found that increased neurogenesis at the hippocampus enhances memory. Rats stimulated by music before birth display an increase in the birth of neurons at the hippocampus, and an improvement in spatial memory. At the molecular level, music upregulates the expression of proteins involved in the survival of neurons, such as CREB, p-CREB, and BDNF. Music may stimulate an improvement in memory through the increase in neurons at this brain area.

The number of synapses of the neurons also increases at the hippocampus. The synapse is a junction that allows neurons to pass chemical signals to another cell for communication. Thus, a neuron with more synapses would be communicating with more neurons. A higher synaptic density has been correlated with improvement in memory. Having neurons that are talking to other neurons more seem to improve spatial memory. Perhaps pre-natal music stimulation changes the expressions of proteins at the molecular level, which allows more neurons to be born and to communicate with one another, leading to an enhancement in spatial memory.

MEMORY CENTER OF THE BRAIN

The hippocampus is an important part of the brain of humans and other mammals. It plays a role in the consolidation of short-term to long-term memory and in spatial memory. Damages to this area of the brain result in memory loss, while increase in neurogenesis in this area seems to enhance memory. Pre-natal music stimulation changes expressions of proteins in this area, which may lead to an increase in neurogenesis.



The effect of music reducing stress and anxiety is also present in pregnant mothers. In a study conducted at the College of Nursing at Kaohsiung Medical University, Taiwan, the researchers recruited 236 pregnant women in their second or third trimester, all with similar backgrounds in occupation, class, education level, and marital happiness. Half were given CDs and listened to music for half an hour each day. They were given the choice of listening to classical music, nature sounds, Chinese children's rhymes and songs, or lullabies.

The other half did not listen to the CD. Although both groups received the same routine prenatal care, mothers who listened to music had a lower level of stress, anxiety, and depression scores even only after two weeks. As the study's author, Dr. Chung-Hey Chen, explained in a news release, "Our study shows that listening to suitable music provides a simple, cost-effective and non-invasive way of reducing stress, anxiety and depression during pregnancy."

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DIRECT OR INDIRECT EFFECTS OF MUSIC?

The mechanism proposed above is that auditory stimulation directly increases neurogenesis at the hippocampus by changing protein levels, leading to an enhancement in memory. However, many debates have been on whether these changes in brain structure are due to indirect effects of music. Perhaps music leads to a secondary effect that causes these differences.

One such effect is the lowering of stress. Music is known to be a reliever for stress and anxiety. Music therapy is widely used and is effective in alleviating these symptoms.

Stress is beneficial during evolutionary development. In the body, stress upregulates a hormone, cortisol, which leads to the body's "fight or flight" response. Cortisol heightens energy metabolism, and suppresses non-immediately needed processes, like immunity and reproduction. However, long-term exposure to cortisol leads to negative effects, such as impaired cognitive performance, lowered immunity and infertility. A high level of cortisol is correlated with increased cell death at the hippocampus.

Both androgens and estrogens are involved in the organization of neurons in the brain. Estrogens regulate important molecules that promote the growth of neurons, such as brain-derived neurotrophic factor (BDNF) and nerve growth factor (NGF) Androgens also increase NGF. In fact, music increases neurogenesis, the regeneration and repair of neurons in the adult brain by altering androgen and estrogen levels. Therefore, music may also enhance spatial memory by indirectly altering levels of these hormones in the body, which leads to changes in protein levels at the hippocampus.

In fact, music increases neurogenesis, the regeneration and repair of neurons in the adult brain by altering androgen and estrogen levels.

Pre-natal stress is also linked to learning deficits. Offspring from pregnant rodent mothers exposed to stress perform poorer in spatial memory tasks. Pre-natal stress affects the offspring in adolescents and even well into adulthood. Not only is spatial memory altered, but the brain morphology is also changed. The animals display a reduced cell growth and accelerated aging in the hippocampus. Furthermore, researchers found more cells dying and undergoing degeneration at this brain region. In these animals, the adrenal gland, the source for cortisol, also increased in size, suggesting that the effects in the brain may be because of an increase in stress hormone in the body. Pre-natal stress affects neurogenesis at the hippocampus through an increase in cortisol, which leads to poorer performance in spatial memory. This is the opposite effect of music, which increases neurogenesis and enhances spatial memory, a medium that also reduces stress and anxiety.

Perhaps music indirectly affects the growing fetus by lowering stress and cortisol in the mother, rescuing these new-born neurons and leading to enhancements in spatial memory.

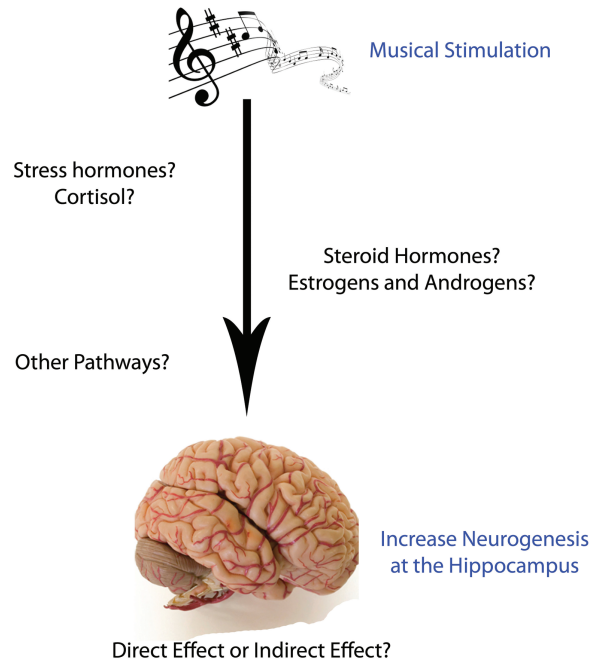
MUSIC ALTERS STEROID HORMONES

Cortisol may not be the only hormone that music affects. Steroid hormones, androgens and estrogens, are suggested to be involved. While androgens are usually referred to as male hormones and estrogens as female hormones, we all possess both types. After listening to music, men have a lower level of androgens, but women have a higher level of these hormones. Estrogen level is also altered by musical stimulation. It has been suggested that music changes our mood, leading to alterations in the levels of steroid hormones in our body.

Our brains are affected by many chemicals. Cortisol and steroid hormones are only a few that have an effect on neurons. There may be many more chemicals involved to explain music's effect on the enhancement in spatial memory.

MUSIC AND ITS EFFECT ON THE BRAIN

Pre-natal music stimulation leads to an increase in the birth of neurons at the hippocampus. Much debate has been around how music has this effect. Some hypotheses include the involvement of hormones, such as stress hormone (cortisol) and steroid hormones (estrogens and androgens).



SIGNIFICANCE IN HUMAN

Music improves spatial memory in rodents and other animal models. However, one criticism is that humans experience and appreciate music different than animals. Can these non-human studies be applied to us?

While there are no studies that look at stimulating pregnant human mothers with music and performing tests on infants, studies do suggest a correlation between musicians and spatial memory. Furthermore, musical training has been found to enhance spatial recognition tasks in pre-school children and improve their learning of mathematics and science. While these effects may be attributed to training and not listening itself, music does seem to have a beneficial effect.

TO LISTEN OR NOT TO LISTEN

To a pregnant mother, the most important question may be, "Should I listen to music then?". While we do not know whether music directly or indirectly affect the brain in animal studies, music does alleviate prenatal stress, which is at least beneficial for the mother. As of now, there are no studies that demonstrate a correlation between music and negative effects. Music also minimizes the distress of labor. While controversies remain on the effects of prenatal musical stimulation on intelligence, there are no doubts that music benefits the mother. A mother should not listen to music expecting to increase a child's intelligence, but listen for her own enjoyment and benefits. Who knows, maybe listening to Wagner helps you relax and give birth to the next Einstein. As Shakespeare wrote, "If music be the food of love, play on"!

More to Explore

Chang, M.Y., Chen, C.H., and Huang, K.F., 2008, Effcts of music therapy on psychological health of women during pregnancy: J Clin Nurs, v.17, p2580-7.

Chaudhury, S., and Wadhwa, S., 2009, Prenatal auditory stimulation alters the levels of CREB mRNA, p-CREB and BDNF expression in chick hippocampus: Int J Dev Neurosci, V.27, p.583-90.

Fukui, H., and Toyoshima, K., 2008, Music facilitate the neurogenesis, regeneration and repair of neurons: Med Hypotheses, v.71, p.765-9.

Kauser, H., Roy, S., Pal, A., Sreenivas, V., Mathur, R., Wadhwa, S., and Jain, S., 2011, Prenatal complex rhythmic music sound stimulation facilitates postnatal spatial learning but transiently impairs memory in the domestic chick: Dev Neurosci, v.33, p.48-56.

Kim, H., Lee, M.H., Chang, H.K., Lee, T.H., Lee, H.H., Shin, M.C., Shin, M.S., Won, R., Shin, H.S., and Kim, C.J., 2006, Influence of prenatal noise and music on the spatial memory and neurogenesis in the hippocampus of developing rats: Brain Dev, v.28, p.109-14.

Lemaire, V., Koehl, M., Le Moal, M., and Abrous, D.N., 2000, Prenatal stress produces learning deficits associated with an inhibition of neurogenesis in the hippocampus: Proc Natl Acad Sci USA, v.97, p.11032-7.

Rauscher, F.H., Shaw, G.L., Levine, L.J., Wright, E.L., Dennis, W.R., and Newcomb, R.L., 1997, Music training causes long-term enhancement of preschool children's spatial-temporal reasoning: Neurol Res, v.19, p.2-8.

Tabarro, C.S., de Campos, L.B., Galli, N.O., Novo, N.F., and Pereira, V.M., 2010, Effects of the music in labor and newborn. Rev Esc Enferm USP, v.44, p.445-52

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