

Foetal learning – a bridge over birth

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The human foetus lives its life protected from the outside world. The sense of sight is limited – only the brightest rays of sunshine reach the uterus. Also, the maternal tissues protect the foetus from outside tactile experiences. The medical view of foetal development is focussed on the development of the lungs and other organs that need to mature enough so that the individual can survive after birth. Traditionally, very little was known about the cognitive development and the role of learning during the foetal period.

Pregnant women have always felt that the foetus is a reactive and communicative “person” already before birth. Women have experienced, for example, the startle reflex of the foetus in the case of a sudden loud sound. Family members have also reported playing a “game” with the foetus: they have pushed the foot of the foetus through the maternal tissues and felt that the foetus is pushing back.

These acts of communication are also supported by scientific evidence. New research on foetal learning, mostly focusing on audition and olfaction/taste, has shown that the foetus is capable of learning and that some reflexive behaviour of the foetus allows simple communicative acts.

The first sensory system to develop in the foetus is the somatosensory system. Already starting from week 8 of the gestational period the foetus is capable of sensing the pressure caused by one hair touching the cheek. The development of the somatosensory system has been shown to be subject to changes related to the environment before birth. For example, the increased amount of somatosensory stimulation in the case of monozygotic twins leads to accelerated motor development compared to dizygotic twins who have no such additional stimulation source as the other twin repeatedly touching and holding the other one when in the same amniotic sack.

Olfaction and taste are a combinatory chemosensory sense in the foetus, since all olfactory and taste sensations are mediated through the amniotic fluid floating in the nasal cavity and the mouth. It has been known for a long time that the amniotic fluid is rich in the concentration of fragrances typical to the mother's diet. These smells and tastes are recognised by the neonate and the neonate even prefers the smells and tastes that he/she was exposed to during pregnancy. For example, if garlic or vanilla was typical in the mother's diet during the last 3 months of pregnancy, the neonate will choose milk which smells of garlic or vanilla compared to milk that does not.

The sense of smell is very different in neonates than what it is in adults. Adults have lost the ability to recognise smells that were familiar during infancy. For example, the neonate can differentiate between human breast milk and milk from a cow, and prefers the human milk. Further, the neonate can recognise his/her own mother's milk even when compared to the breast milk of other mothers who gave birth the same day. And this skill does not require training: even neonates at the age of a few hours who did not yet get to taste milk are successful in recognising their own mother's milk. This ability requires learning during the foetal period. The mother's diet and personal fragrances become familiar to the foetus, and are remembered and recognized after birth.

In contrast to these learning-related findings, there are results that show that not everything in the neonatal life can be changed and determined by the environment. There is a natural preference for human milk in neonates, and this preference persists even in those neonates who never receive human milk. Thus, even though a neonate fed with formula milk will certainly learn to connect the smell of the formula milk to the satisfaction of a full stomach, the preference for the human milk is still stronger and overrides this learning effect. These types of innate preferences are of course very important for survival since the milk of other species is never optimal for a neonate in a natural environment.

This interplay of innate preferences or skills and experience-based learning is very interesting especially in the light of foetal learning. During the foetal period, the foetus is capable of extracting information from the environment in the uterus, and even from the environment outside the maternal tissues. An especially powerful tool for this purpose is the auditory system.

The auditory system matures much later than the somatosensory and chemosensory systems. While the sensations of touch, smell and taste are available for the foetus from the early weeks and months of pregnancy all the way until birth, auditory information starts to activate the ear and the brain only starting from mid-pregnancy onwards. The auditory system, thus, has much less time to adapt to the environment than the somatosensory and chemosensory systems. It should also be pointed out that while the cortical structures are very important in the adult auditory and somatosensory systems, the foetal systems most probably do not utilise the cortical areas in these tasks, since the auditory and somatosensory cortical areas are not matured and active in the foetus. In contrast, for the smell, the cortical areas are not at all that important even in adults. This leads one to think that smell is the sense that could be most effective in the foetus since many of the structures needed for the smell sensation in adults are already mature during the foetal life. The smell is an “evolutionarily old” sense, utilising the “evolutionarily old” parts of the brain which are similar between humans and simple species like lizards. These parts of the brain are also the first ones to develop during the foetal period. The memories stored in these parts of the brain differ greatly from those stored by the cortical-hippocampal system that matures around the age of 3 years in humans. Still, the “old” parts of the brain are capable of storing information and are active throughout life.

The data that describes the development of the auditory system during the foetal life is mostly gathered by viewing the foetus with ultrasound or monitoring the changes occurring in foetal heart rate with respect to sounds. With ultrasound, startle reflexes to loud sounds, and eye blinks and head, hand and foot movements to softer sounds can be observed starting from 24 weeks gestational age (GA). From prematurely born infants, after week 24, brain responses to sound stimuli can be recorded. These responses become stable and repeatable at the age of 30 weeks GA.

What does the foetus hear? It was long believed and even recorded with microphones inside the maternal abdomen that frequencies between 100 and 500 Hz would be heard by the foetus, but that the higher frequencies would be mostly reflected and filtered by the maternal tissues. Later research seems to prove otherwise. Recent studies with modern underwater microphones suggest that all frequencies up to 3000 Hz would be heard quite well by the foetus. These new studies also suggest that the background noise level

produced by the maternal organs would be clearly lower than what was thought before. All researchers agree on the fact that the foetus is capable of hearing the mother's voice very clearly due to "bone conduction", the fact that the mother's voice does not travel to the foetus through air but directly through the mother's body.

The auditory information obtained by the foetus is not left unnoticed. On the contrary, the foetus is very actively memorising the material and is capable of using these memories after birth. For example, the neonate is able to recognise his/her own mother speaking compared to another woman speaking the same language. The neonate is even capable of recognising the mother's voice when the mother speaks a foreign language. Experimental work shows that this recognition is done slightly differently from the way an adult would perform the same task. Adults recognise familiar voices mainly on the basis of the acoustic characteristics of the glottal pulse and the vocal tract, the so-called tone, or colour, of the voice. This is not important to neonates, however. The neonates recognise voices on the basis of prosodic features, that is, on the basis of stress placed on syllables, the contour of the voice going up and down in frequency, and the typical alterations of speed during speaking. This difference in practise means that while adults can recognise a familiar person's voice even when the person is speaking in an unnatural way, neonates may not be able to do so.

During the foetal period, the foetus typically has 3 months to get used to the characteristic features of the mother's voice. At birth, the neonate is capable of recognising the mother on the basis of this learning. Also, other people who have frequently spoken with the mother are recognised by the neonate. The constant exposure to the human voice during pregnancy helps, in my opinion, the neonate to direct his/her attention towards the human voice also after birth. This is a very important step on the long road towards understanding and producing speech. When somebody is speaking to the neonate, there are typically other simultaneous sound sources. These sources, in the absence of the ability to direct the attention towards speech, would ruin the possibilities of the neonate comprehending speech.

Music is very powerful in producing foetal memories. When the mother frequently listens to music, the foetus will learn to recognise and prefer that same music compared to other music. The foetus will build the same musical taste with his/her mother automatically,

since all the hormones of the mother are shared by the foetus. One could say that the mother and the foetus are in the same emotional state all the time due to the hormonal sharing. This sharing continues in breast-fed neonates even after birth through the milk, and only slowly after birth the neonate starts an “independent” life without hormonal regulation from the mother.

The same musical taste and the recognition of the family voices and sounds can be viewed as a means of adjusting to life after birth. The foetus already has an “auditory home” to which he/she is born. The familiar sounds and voices, together with familiar smells and tastes, build a bridge between the foetal life and life after birth. Even though many things seem to change at birth—the tactile experiences are new, the task of breathing air and sucking milk are hard, and the sensations of cold and heat are previously totally unknown to the neonate—at least the voices and smells are something to be remembered from the life before birth. These experiences make the neonate belong to a certain family, to a pre-defined environment with familiar sounds, voices and smells. The neonate is not a tabula rasa, the experiences have formed his/her brain to be responsive and to prefer certain sounds and smells, and thus connect the neonate to the surrounding family and environment.

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