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# Pre- and perinatal auditory experiences and their importance in the development of the child

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The interest in the impact of prenatal experiences regarding the sense of hearing on the postnatal life may be traced back to ancient times. Already then, Confucius (500 BC) expressed the belief that what happens before birth may determine one's further life. Women in ancient China closely followed certain rules concerning prenatal care of the child, including those related to their well-being and stimulating the child, also with music. Pregnant women appreciated the importance of rocking the child to the rhythm of dancing and tunes sung by themselves. In his *De Generatione Animalium,* Aristotle (300 BC) wrote that already before birth the child receives the first sensory impressions. In the Bible, there is also a clearly expressed belief in auditory perception by the child before birth, expressed by the words of Elizabeth, who addresses Mary confessing that "as soon as the sound of your greeting reached my ears, the baby in my womb leaped for joy" (Luke 1, 44, New International Version). The Infant heard the voice from the environment of his mother and reacted with joy to its positive emotional message. Similarly, the Indian surgeon Susruta (400 AD) claimed that the child is seeking stimuli already at the end of the first trimester and his/her mind is operating from the fifth month of the prenatal development. Also in the Japanese tradition, mothers were trying to create the best conditions for the development of their child in the womb through the practice of Tai-kyo (teaching-womb), which entailed initiating contact with the child by rhythmic tapping on the abdomen at regular intervals, listening to music and visualizing the person of the child. It was believed that such type of stimulation has long-term consequences for its development (eg. http://www.babyplus.com/TheScience.php. Access: 04.11. 2012).

Hundreds of years later, John Locke argued that based on sensory stimuli the fetus is capable of creating certain "simple ideas" that are subject to the process of thinking (1690). Wilhelm Preyer believed that the brain functions start before birth (1895). According to J. Śniadecki, the baby has "origins" of mental powers, and "it has motion, feeling, uses the senses and receives external sensations" (1804, 1997). The belief in the sensual capabilities of the child before birth and specific knowledge about human prenatal development was gradually becoming more and more established.

The multiplicity of research on the sense of hearing conducted in the 20th century and the popularization of the results led to a relatively widespread belief that this sense is active before birth. For example, French and Canadian studies revealed that pregnant mothers claim that in about the 25th week of gestation, all the senses are already working, and half of the mothers were of the opinion that their child was experiencing emotions. The common perception of mothers is that the child is sensitive to music and playing an instrument or listening to music is positive for his or her development. This view has been made increasingly common and established in the social awareness thanks to the advertisements of special audio collections, e.g. CDs especially prepared for pregnant parents, with recordings of music, songs, lullabies and various sounds, such as the mother's heartbeat or nature, as well as devices for listening, including special "walkmans for the fetus" (Kisilevsky et al. 2004).

The same belief concerns the neonatal period and infancy, and its significance is visible in various initiatives, such as the one by the governor of Georgia in the United States, who at the state budget meeting (13.01.1998) proposed to spend $105,000 on audio CDs with classical music to be given to each of the 100,000 newborns per year leaving the hospital in this state. Accompanied by the sounds of the Beethoven's *Ode to Joy,* he argued that there is no doubt that listening to music at a very early stage of development has a positive effect on the spatial-temporal reasoning, which underlies achievements in mathematics, technology, engineering, and even a game of chess. Listening to soft classical music supports the development of trillions of neural connections created then in the brain (Sack 1998a). The controversy was, however, whose music would have the best soothing and stimulating effect for the development of young children, which composers and what kind of music should be included: Mozart and Tchaikovsky, or rather Brahms, Rossini and Saint-Saëns (Sack 1998b). In the most common worldwide conviction it is the music of Mozart that has the best impact on the development of intelligence (see the debate on the issue called "the Mozart effect" – Don Campbell 1997, 2000; Gorman 1999; McKelvie, Low 2002). However, it should also be mentioned that in the opinion of many people most of the evidence on pre-birth experiences affecting later childhood or adulthood is anecdotal, unscientific, and based on subjective interpretation.

Our knowledge about prenatal auditory capabilities has been expanding more and more, not only in terms of the growing number of methodologically correct studies, but also in terms of the popularity of the issue in the public opinion. An increasing amount of information on this topic is possible to be found not only in textbooks (Kornas-Biela 2004, 2011) and professional studies in the field of developmental psychology (Kornas-Biela 1992, 1994; Maurer, Maurer 1994; Vaughan 1997; Holinger 2006), but also in popular Internet sources and in guides of various types.

## Methodological aspects of testing the sense of hearing before birth

The history of empirical research on the sense of hearing before birth dates back to the 1920s. It is then that the prenatal child's motor reactions to the sound were first tested. Most often it was the sound of a car horn, a loud bell, an alarm clock or other device situated close to or directly touching the mother's abdomen. One of the first studies involved recording the baby's movements after a series of sounds made by the car horn. It turned out that after a series of the same sound the child accustomed to the stimulus and the motor reaction disappeared (Peiper 1925). Thanks to the behavioral manifestations of the child's auditory activity perceived by the mother in the second half of pregnancy (movements, strong kicking in response to the sound), hearing has become the first and the most experimentally studied sense of the child before birth. The first studies of the auditory capabilities were also carried out through observing the behavior of premature newborns to investigate the child's ability to receive and respond to stimuli from the sense of hearing in a way that had not been possible to study otherwise due to difference of the intrauterine environment that may have not allowed to disclose these capabilities. At present, auditory competences discovered in preterm infants are still treated as an indicator of the auditory skills of the child before birth.

Since the first studies on this matter, the techniques of testing prenatal hearing have changed significantly. The development of more accurate methods of studying the child's response to sound stimuli of different types, such as 3D and 4D ultrasonography (USG in real time), cardiotocography (CTG), electroencephalography (EEG), and magnetoencephalography (MEG) allowed a more precise investigation of this sense before birth. Many of the auditory functions of the prenatal child are also measured using such methods as classical conditioning, habituation and exposure learning.

Also animal studies are very helpful in understanding the functioning of sense of hearing in humans before birth. From studies carried out using a hydrophone transmitting sounds, implanted inside the amniotic sac of an animal, it is known that the sound environment changes with the progress of the pregnancy, especially during childbirth there is a change in the frequency of the waves that are conducted without distortion (Vince et al. 1985). Through reasoning by analogy, the animal model provides interesting information on the auditory perception, remembering auditory sensations and their importance in the process of adaptation after birth in humans. Primarily ethical, but also technical limitations do not allow for the research of many phenomena in the prenatal child, hence, studies on animals such as rats, chimpanzees, and sheep provide valuable information (Kornas-Biela 1994).

### Audibility and hearing in the intrauterine environment

The intrauterine environment is relatively loud – approximately 60-70 dB. It is reached by the sounds from inside the mother's body (movements of the diaphragm, gurgling of the stomach and intestines, heart rate, noise of the circulation in the blood vessels, bone and joint movements, treading), her voice, as well as other sounds of the environment. The mother's voice is an important part of the intrauterine environment (Querleu et al., 1988).

The sense of hearing is one of the senses that is growing very fast. The structure of the sense of hearing develops during the first 20 weeks after conception. The most important of its parts is the cochlea in the inner ear and the auditory cortex in the temporal lobe. The first structural elements of the sense of hearing are bubbles that appear in the 4th week. The 3rd week of fetal life brings the development of the auditory vesicles. The inner ear is formed by 5th week. In the 7th week the earlobe takes the shape after the child's parents (Kornas-Biela 1991). The differentiation of cells in the cochlea (stereocilia) begins between 10th and 12th week of gestation. The eardrum develops from the ectoderm and the ossicles from the mesoderm. This development continues until the 8th month of intrauterine life. The cochlea, the hearing organ of the inner ear, finishes its morphogenesis by the 10th week, and in the 5th month of gestation it reaches its final size (7mm) (Relier 1994, p. 103; Kornas-Biela 2011, p. 155). Early studies by Einsenberg (1965, 1969) suggest that the sense of hearing develops between the 16th and 20th week of gestation. The author also mentions that about 20 weeks of gestation, the child's sense of hearing is developed as an adult one (see: Manturzewska, Kamińska 1990; Kornas-Biela 1991).

Audibility in the amniotic sac depends on many factors (e.g. thickness of the abdominal fat in the mother) and on the characteristics of the stimulus itself, moreover, its perception also depends on the child's age (Hepper, Shahidullah 1994, Lecanuet et al. 2000). Already in a study published in 1981, Querleu, Renard and Crépin proved that the child is able to hear not only stimuli coming from the internal environment of the mother, but also external sounds above or below the base volume – and responds to this stimulation by movements and changes in the heart rhythm. However, a response to a sound stimulus occurs only when the baby is not in distress.

Shahidullah and Hepper's study (1994) demonstrated the gradual development of the ability to hear. From approximately the 20th week of gestation the child begins to detect very strong vibrations and sounds, and reacts by restlessness, rapid eye movement, awakening from sleep, and accelerated heart rate (Joseph 2000). The child initially perceives the sounds in a non-acoustic way and gradually acquires the ability to differentiate the volume, pitch, duration, rhythm, and accent of the sounds. The child first hears the vibration, then strong individual sounds, very loud music, then weaker sound sequences such as human speech, music, singing. At 24 weeks about 50% of children respond to the strong sound by a delayed reaction of fright. Low sounds rather inhibit motor activity of the child, while high-pitch ones increase and accelerate it (Kornas-Biela 2011).

The development of the neural part of the sense of hearing, however, takes place later, and in about 25th week of gestation the auditory system is already operating. Neuronal connections to the auditory cortex are functionally efficient about 28-30 weeks after conception, but take several months to reach maturity. The most critical period for the formation of neural connections between the organ of hearing and the auditory cortex is in the period from 25 weeks of gestation to 5-6 months after birth (Graven, Browne 2008; Kral, Pallas 2011). For the capability of tones to develop, stimulation is necessary: access to stimuli, their differentiation and grasping the significance of the sounds.

Moreover, reactions to sound frequencies higher or lower than the frequencies audible by the human ear have been registered in the prenatal life, which indicates a reception of a different nature than auditory. Certain researchers point out that the sound in the aquatic environment is transmitted through the skull bone rather than through the outer and inner ear (Gerhardt, Abrams 1996 ). Yet, the question whether a child with a conductive hearing loss is prenatally less “impaired” (less impaired bone conduction) than a child with a sensorineural hearing loss still remains unanswered.

The prenatal child begins to respond to sounds between the 22th and the 24th week (Hepper, Shahidullah 1994). A better perception of stimuli of lower frequency (<500 Hz) has been observed (Gerhardt, Abrams 1996, 2000). As the child develops, also the ability to identify sounds of lower volume (decibels) is gradually increasing (Kisilevsky et al. 2004). In addition, at first the child only responds to sounds at low frequencies (250-500Hz, as opposed to the adult: 20-20000Hz), but then the ability to receive a wider range of frequencies gradually increases. Because the child more quickly and clearly hears sounds at lower frequencies (they are better conducted), it perceives music of the bass, cello, bassoon, or flute better than e.g. the violin.

Later, the child acquires the ability of hearing the mother's voice and voices from the environment (Lecanuet, et al. 1993). The sounds come through the mother's body, thus, they are suppressed, but low frequency tones are weakened to a lesser extent (the basic frequency of the human voice is 125-250 Hz – Hepper 2005). Querleu et al. (1988) and Benzaquen et al. (1990) observed that the voice of the child's mother is received at about 10dB higher than a female or male voice with the same pitch as the voice of the mother. The same phenomenon of better audibility (higher volume) of the mother's voice rather than other voices from the environment was also noted by other researchers (e.g. Richards et al., 1992).

## Differentiation of sounds

Prenatal auditory competences have been well described, not only for animals, but also for humans, but the animal model is still often in many studies. Before birth the child acquires a relatively high capacity to discriminate sounds (Chelli, Chanoufi 2008).

Studies on the preference of newborns to hear certain sounds rather than other ones demonstrate that in the period before birth already occurred such processes as receiving sounds, discriminating among them, and remembering differences in the rhythm (the child clearly prefers calm sounds with a steady rhythm, similar to the heart beat of an adult in the state of rest), and distinguishing voices that he or she is regularly exposed to (e.g. mother's voice – DeCasper, Fifer 1980; DeCasper, Spence 1986; Spence, DeCasper 1987), as well as the language (Moon, Cooper, Fifer 1993), parts of speech or music and songs. The prenatal experiences of receiving various sound structures are stored and are the basis of acoustic preferences after birth (Fifer, Moon 1989).

Shahidullah and Hepper (1994) investigated the behavioral manifestations of the child's physical reaction to pure tones with a frequency of 100Hz, 250Hz, 500Hz, 1,000Hz, and 30,000Hz, by children aged 19-35 weeks of gestation. The sounds were emitted from a speaker mounted on the mother's abdomen. The children's reactions were recorded using ultrasound technology. It turned out that the first reaction was movement to the sound of 500Hz at 19 weeks. Then developed the ability to register sounds of lower frequencies, 100Hz and 250 Hz. Altogether, 96% of children at the gestational age of 27 weeks were able to respond to the sounds of 250 and 500Hz, but not to higher tones (1,000Hz and 3,000Hz). The children developed the ability to hear these tones (as tested by the motor reaction) only about the 33rd-35th week of gestation. If in the period preceding birth (116 children, aged 36-39 weeks of gestation) the children listened to pure tones (e.g. of the piano, D4: 292-1,800Hz and C5: 518-300Hz), their heart rate dropped every time when the sound was different than the previous sound (Lecaunet et al. 2000).

The prenatal child not only has the capacity to receive sounds of different frequencies, but also acquires the ability to distinguish them (Lecanuet et al. 1987; Shahidullah, Hepper 1994). The child picks up vowels from the flow of the speech, as they have a lower frequency than consonants, and distinguishes them (Gerhardt, Abrams 2000).

Research conducted within the paradigm of habituation on children aged between 27 and 35 weeks of gestation indicated that all children are able to distinguish pure tones of 250Hz and 500Hz, and syllables such as 'baba' – 'bibi' and 'babi' – 'biba' (110 dB) at 35 weeks of gestation, while at the age of 27 weeks this capacity is not yet well developed. As observed in studies by a team of researchers from France and the USA (Lecanuet et al. 2000), the child is not only able to distinguish sounds ([a] and [i]; 80-110dB) and syllables ('ba-ba' and 'bi-bi'; 110dB), but also the male voice (80-100Hz) from the female voice (165-200Hz), although the loudness, speech duration, type of words and their prosodic features were the same. Interestingly, the study showed that the heart rate slowed down a few seconds after the sound and it returned to normal a new sound appeared or there was a change in the sequence. Already before birth occurs the ability – later possible to be confirmed in newborns – to differentiate between acoustic stimuli, and to perceive changes in their presentation, based on a short audio sample. In other words, before birth of the child attains the ability to perceive changes in the organization of the sound stimulus (Lecanuet et al. 2000).

The prenatal child's skills to differentiate sounds of different frequencies are possible to be observed by magnetoencephalography. An analysis of the potentials evoked in response to the changing frequencies of tones in a series of repeated sounds indicated the child's ability to discriminate them at the brain level at as early as 28 weeks of gestation. With the next week the latency response time was decreasing (Draganova et al. 2007).

**The speech and music**

Many studies have shown that the prenatal child is able to grasp sufficiently accurate necessary information from the sounds heard so that it is able to perceive auditory-specific patterns of hearing, as in the case of human speech. The ability to tell the difference between the sounds at different pitch is an important factor in the development of speech perception (Lecanuet et al. 2000). The ability to receive and distinguish sounds of different frequencies, including the different sounds of speech is essential to the assessment of the child's hearing and speech development, its perception and active speaking. The prenatal child perceives particular prosodic and phonetic qualities of speech especially if it is at the volume above 60dB (eg. Smith et al. 1990).

Various studies on the development of auditory abilities documented that the prenatal child hears the speech of the mother (the best), notices the typical characteristics of her speech, thereby learning the mother tongue, which then provides the basis for learning the language after birth. The mother's speech attracts the most of the newborn's attention and arouses his/her emotions (Cooper, Aslin, 1989). In a study on 14 healthy preterm infants aged 31-34 weeks, who were monitored 4 times a day for 3 days during the first week after birth, it turned out that the mother's voice played from a recording caused a decrease in their physical activity, an increase in alertness, stable heartbeat, a livelier facial expression and gaze, no symptoms such as trembling or loss of body color (Bozzette 2008).

Hepper, Scot and Shahidullah (1993) followed the neonates' behavior in response to the mother's voice and the voice of persons unknown to the child. They noted a difference in the babies' movements in response to both these voices. It turned out that the change in the child's movement is more pronounced in reaction to the mother's voice. Moreover, a more vivid and positive reaction occurs when the mother uses the so-called 'motherese' than when the child hears her voice characteristic for adult speech.

The mother's language spoken to the newborn was called infant-directed speech – IDS, child-directed speech – CDS, caretaker speech, maternal language, popularly also called motherese, parentese, baby talk, mommy talk or daddy talk (e.g. Papousek, Papousek 1984; Eliot 2003, pp. 337-338). Infants react more positively to motherese than to ordinary adult speech. This language has been well explored as a stimulator of speech acquisition by the child after birth, but the prenatal experiences are the important initial base for this process.

A special type of sound is music. The prenatal child gradually becomes sensitive to music (Kornas-Biela 1993; Relier 1994, chapter 6). The ability to receive low frequency sounds develops  faster and are better conducted. James, Spencer and Stepsis (2002) reported a group of children who listened to music, compared with the control group. The "music fetuses" displayed a higher mean fetal heart rate, higher fetal heart rate variation, and a higher count of changes in the body position over time, compared to the control group. Similarly, in another study conducted at 33 weeks of gestation, a higher heart rate was observed in the children while listening to music (Kisilevsky et al. 2004). The child is more sensitive to the rhythm of music rather than to the pitch (Gerhardt, Abrams 2000). There has been a preference for children to listen to quiet music, with a steady rhythm and tempo similar to the heart rate of an adult at rest. That is also why the low-pitch musical instruments mentioned above (such as the bassoon, flute and cello) are recommended to mothers for listening during pregnancy.

However, it is also important do not overdo in attributing prenatal stimulation an excessively important role, because early exposure to music from the prenatal period is only one of many factors affecting whether the child would be e.g. musically gifted in the future. In addition to prenatal exposure to music, such factors are also important as: interest in music, time that the child spends on contact with music, a positive image of oneself as musically talented, motivation and hard work (Kaminska 2002, p. 39). These basic factors determine whether music is becomes a field of one's interest and activity.

**Prenatal acoustic learning and the impact of prenatal experiences on the whole life**

Sounds provide experiences for prenatal child. As Abrams and Gerhardt (2000) stated "The acoustic environment of the fetus is composed of continuous cardiovascular, respiratory and intestinal sounds that are punctuated by isolated, shorter bursts during maternal body movements and vocalizations", and of course by sounds external to the mother's environment. Additionally, vibrations on the external surface of the maternal abdomen are also able to induce sounds inside the uterus.

Over the next weeks in the third trimester of prenatal life child is observed to be capable of improvement in terms of auditory habituation – adaptation to the sound that occurs constantly, for a long time or is frequently repeated (Hepper 1992). A study on the prenatal children's skills to recognize a musical stimulus played on TV has shown that at about 30 weeks of gestation the prenatal child is able to recognizes the given sound stimulus as familiar and livens up (Hepper 1991). Other researchers have confirmed that this period is appropriate for developing the ability to recognize well-known sounds, and even suggest that this capacity may possibly be acquired earlier (e.g. Springen 2010).

A special type of sounds that accompany the child throughout its whole life before birth is the mother's heartbeat and the sounds of the work of her internal organs. They are a constant feature of the intrauterine environment and alongside with the mother's speech they are subject to habituation and remembering. Imprinting concerning the maternal heart rate causes that the baby held by the mother at the breast has a sense of continuity of experience, feels safe, calms, relaxes. Premature babies who can hear this rhythm (even from a recording) cry less, have less difficulty with breathing, eating and sleeping, and less frequently fall ill (Sadowski 2001, p. 468). Mother of all cultures intuitively fulfill the need of the newborn in this respect by carrying or holding the baby with the head on the left side of her body, and by breastfeeding. A similar calming effect on children (and adults) has the rhythmic ticking of the clock, the sound of the metronome or a fan, the sea waves, the church bells, the wheels of the train, as well as listening to the rhythm of a person breathing.

The prenatal child remembers sounds that are often present in the environment. As development increases its ability to habituation, that is, the frequency of a lack of reaction (such as cessation of body movements, increased heart rate) after a series of vibroacoustic stimuli, which reflects increasing maturity of the neurophysiological processes that allowing an identification of the given sound as familiar. Therefore, the prenatal child stops responding to even strong but repeated sounds in the surrounding environment, and does not react to them as a stressor either before or after birth. Newborns of mothers who have lived near an airport since before the 5th month of pregnancy rarely cry or awaken at a passing aircraft, while half of the infants whose mothers moved into the vicinity of an airport just before birth wake up and experience anxiety. Most newborns regularly exposed before birth to loud disturbing (alarming) sound, did not respond to it with fear, while infants who had not been accustomed to such sounds in the womb clearly expressed their astonishment and fright (Damstra-Wijmenga 1991).

The child registers the mother's voice in the memory. The preference to hear the voice of the mother rather than the voice of another woman is visible in the newborn immediately after birth and is independent from the length of time that passed after birth (research until 2 years of age) or the feeding method (DeCasper, Fifer 1980; DeCasper, Spence 1986; Fifer, Moon 1989; Hepper Scott, Shahdullah 1993). In a study conducted on a group of 28 newborns on the second day after birth, it turned out that over half paid particular attention to their mother's voice, while not reacting to the voice of another woman (Damstra-Wijmenga 1991).

The above was confirmed by experiments, for example, neonates very quickly learned such way of sucking that enabled them to listen to the voice of their mother or sucked in such a way as to listen to the story "familiar" to them from before birth, rather than one with a different rhythm and quite new to them. Newborns prefer to listen to the female voice rather than the male one, and generally to the human voice rather than to any other sound or silence.

The auditory memory of the mother's voice results in faster learning the mother tongue. It also manifests itself in the fact that in a bilingual environment the child learns faster the language that the mother spoke during pregnancy. Also, bilingualism in babies starts in the womb. A recent study by Canadian and French researchers shows that babies of mothers have different language preferences than babies born to monolingual mothers. [http://blog.babyplus.com/prenatal-brain-development-linked-specialized-sound/02.12.2012].

Prenatal listening exercises allow the infant to respond to human speech and to adapt their movements to the rhythm of the speech it hears in the environment (the child "dances" with its body to the rhythm of the adult's speech), while adults spontaneously meet the preferences of the newborn and use higher pitch and affectionately-sounding clusters (the motherese/baby talk mentioned above, Eliot 2003, p. 337-338). Children pick up and remember the prosodic features of the language their mother spoke during pregnancy and not only learn that language faster, but also learn to distinguish the emotional components of speech (which correspond to the physiological messages that reach the child) and after birth are able to distinguish the emotional speech patterns of their mothers (Mastropieri, Turkewitz 1999). The mother's voice, as a sound breaking the silence is the 'primary object' for the child, the precursor of the internalized object, which the mother becomes for the baby after birth.

Even premature infants, when exposed to recordings of their mothers' voice (speaking, reading fairy tales, singing), the heartbeat or sound of calm music, played from small speakers placed in incubators – overcome difficulties of the preterm period more successfully (they cry less, have less difficulty in breathing, are less often sick, suck and sleep better, gain weight faster). Obviously, technical devices imitating the intrauterine environment are not able to substitute the child's direct contact with the mother. It is also unclear whether artificial, prolonged and frequent repetition of stimuli from the period of life that has passed does not disturb the child's openness to new stimuli and contacts (e.g. if it does not constrain the child or arouse the desire to escape to the previous prenatal state).

The prenatal child remembers fragments of songs the mother sang (Relier 1994; Trehub, Trainor 1998) and fragments of music regularly heard in the womb

(Gerhardt, Abrams 2000; James, Spencer, Stepsis 2002; Hopkins et al. 2005). Music played to prenatal children for several hours, at intervals, for three days before birth through headphones attached to the mother's abdomen caused a change in the rhythm of the children's heartbeat and behavior and was remembered. In the period of 3-5 days after birth the same music induced a change in the behavior and a longer time of alertness in children who had the opportunity to listen to it before birth (10), compared to children whose headphones emitted no sound (10) (James, Spencer, Stepsis 2002).

Many researchers emphasise that pre- and perinatal exposure of the child to the sounds of music has long-term positive effects on its development (Hurwitz et al. 1975; Douglas, Willatts 1994; Costa-Goimi 1997; Rauscher et al. 1997; Rauscher, Robinson Jens 1998). The child remembers fragments of music the mother often listened to during pregnancy (e.g. the jingle or clip from a show – Hepper 1988, 1991), and her singing (e.g. Relier 1994, chapter 6). In experimental studies it was found that children of mothers in their 37 week of pregnancy reacted, by slowing down their body movements, to the opening tune of a soap opera watched regularly by the mother ("Neighbours"). The same children, as 2- to 4-day old newborns recognized the tune, stopped moving or crying, and their heart rate slowed down. However, if after birth they had no contact with the tune for three weeks, the memory weakened and the ability to recognize it as familiar disappeared (Hepper 1988). Emitting such familiar sounds after birth has a calming effect and supports the development of the child.

A study carried out in Thailand (Department of Obstetrics and Gynecology, Hua Chiew Hospital in Bangkok) aimed to assess the capacity of the prenatal child's memory and learning in various senses. 120 pregnant mothers were trained to enrich their auditory environment by using the heartbeat sound, music, rhythmic patting and rocking. They study suggests that "giving a baby an enriched auditory environment before birth really can make a difference in the prenatal brain development". The experiment also resulted in a better relation between the mother and the child after participating in the prenatal activities, which may be an effective way to support the bonding between the mother and the child and promote the infant's emotional and intellectual development [http://blog.babyplus.com/ prenatal-brain-development-linked-specialized-sound /04.12.2012].

## The sense of hearing and its inter-sensory relations

Pre- and postnatal sensory experiences shape the functional architecture of the brain (Pallas 2005). The sense of hearing is not the only acting sense, on the contrary – during the prenatal stage of life all the senses are active: from the end of the third month of the other senses reach their functional efficiency, e.g. at the turn of the 3-4th month the baby perceives the basic tastes and the smell of the amniotic fluid, in the period of the 7th and 15th week the whole body gradually becomes sensitive to touch and pain sensations (Kornas-Biela 2011). The fact that all the senses work long before raises a question on the cooperation of the sensory modalities (Busnel, Granier-Deferre, Lecanuet 1992) and the possible dominance of one sense, as it occurs in infancy (Bremner, Lewkowicz, Spence 2012). The cooperation among the senses remains a phenomenon that we do not know much about, as studies have mainly focused on the understanding of each sense separately. However, the prenatal neural structures may possibly play a mediating role in collecting impressions, e.g. at the absence of a developed receptor, the stimulus may be received by sensory modalities that are developmentally more advanced or by a non-specialized neural system (Hepper 1992, pp.133-134). Studies on newborns and infants suggest that there is an interaction among the senses, hence, an assumption may be made that it also occurs to a certain extent before birth. It is possible that in the near future the cooperation among the senses will become an interesting field of investigation.

## Prenatal hearing test

Many authors point to the usefulness of the auditory evoked response (AER) test for predicting neurological disorders in newborns, delays in the neuro-motor development (e.g. hydrocephalus), and for the diagnosis of hearing loss before birth. However, with the current state of technology, the still too many false negative results do not allow a solid base for reliable diagnoses. Nevertheless, the AER test is particularly useful in the diagnosis of severe brain damage and brain death (Lowery et al. 2009). On the other hand, the AER tests may in the near future be a very precise diagnostic tool to examine the functioning of the brain and may be used to predict the child's cognitive abilities (Sheridan et al. 2010).

Testing the child's auditory reaction before birth indicated its predicative value. Namely, when the child's spontaneous motor reaction was observed, alongside with a reaction induced by an acoustic stimulus (on a group of 260 children from high-risk pregnancies and 233 children from low-risk pregnancies) it was found that children of mothers with high-risk pregnancies were characterized by atypical forms of a response to the sound stimuli. These results suggest the need for further research on the relationship between the operation of the child's sense of hearing before birth and language skills after birth (Kisilevsky, Hains 2005).

At present, there is rich literature on the usefulness of the sound test (fetal acoustic stimulation) and the child's response. The type of movements and changes in the heart rate are used to assess the possible perinatal risk. This test is non-invasive, safe and is a fast screening method for evaluating the child's well-being, which allows to identify children at the risk of developmental disorders or problems in the progress of labor (e.g. Tannirandorn, Wacharaprechanont, Phaosavasdi 1993).

Prenatal auditory abilities are of clinical relevance. The child's ability to notice the differences between sounds of different frequencies belongs to the important conditions for the proper development of the cognitive functions, and problems in this matter are clinical manifestations of disorders of hearing after 28 weeks of gestation. Therefore, the magnetoencephalograph test – that diagnoses the evoked potentials in response to the changing frequencies of sounds, in a series of repeated sounds (and thus, tests the child's ability to distinguish them) – is an important method in the prenatal diagnostics of neurological disorders or hearing (Draganova et al. 2007).

**Summary**

Studies on the prenatal sensory abilities provide knowledge about the potential of the child that is born. However, the acoustic stimuli that are belong to the normal prenatal experience are different from those that the child perceives in the physical and personal environment after birth. Nevertheless, all the senses are functionally active before birth and the sensory impressions are gradually integrated into simple perceptual schemas.

We also have to remember that due to the high prenatal sensitivity to sounds, one should follow the principles of sound safety. The prenatal child's sensitivity to low frequency sounds indicates the need to protect it from loud low-pitch sounds, as they may cause damage to the sense of hearing (Hepper Shahidullah 1994). Loud and continuous (prolonged, uninterrupted) sound and impulses emitted by devices or electronic instruments with low frequencies may damage the cells in the cochlea and lead to hearing loss (Gerhardt, Abrams 2000). The more frequent the child's exposure to loud sounds, the greater the risk of hearing loss (Relier 1994, p. 106; Eliot 2003, pp. 326-327). Thus, properly designed prospective randomized control studies on different sounds should involve long-term follow-up observations of subjects and controls to examine the duration of such effects and their potential harm (James, Spencer, Stepsis 2002, p. 348).

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