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Prenatal programming-potential modulator for development of personality, preferences and skills

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Abstract
Background: It was believed that an individual develops his or her personality, preferences and skills due to the influence of various external factors including environment, society, and culture. However, recent studies indicate that this development starts prenatally and that the activities that a mother indulges in, during pregnancy influences fetus personality and skills largely.
This study was undertaken to analyze researches and experiments conducted and published in indexed journals to understand the bond between the mother and her fetus and its implications on various aspects of an individual. Theories could then be postulated on probable ways to modulate the fetal preferences in utero for future effective functioning of the individual.
Discussion and Conclusion: Multiple studies have shown that the fetus develops an inclination for certain prosodic features while still in the womb, which influences their preferences for certain auditory and linguistic features later in life. There is compelling evidence that the flavor of food consumed by mothers during pregnancy and lactation, pave the way for the creation of a desire for a familiar taste in the offspring. Prenatal stress and depression in the mother can lead to major psychobiological changes in the baby and they were more likely to develop a similar temperament later in life. Many studies also showed a strong correlation between maternal brain activity and fetal cerebral blood flow, resulting in long and short-term neural changes in the fetus and eventually, the infant.
In conclusion the activities undertaken by the mother and her emotional state during pregnancy significantly influences certain aspects of a person's personality, preferences and skills, which starts in utero and persists in later life.

Keywords: Maternal influence, developing fetus, language, cognition, preferences

Introduction
The intense psychological and physical bonds shared by a mother and her fetus is unique and begins during gestation when the mother provides the developing fetus with warmth and sustenance. At birth, newborns were thought to have limited cognitive abilities akin to a blank canvas. It was thought that the data required for processing abilities only develop with sensory experiences outside the mother's body. Current development of research in this subject indicates that these assumptions were completely wrong. In fact, it has been proven that newborns have already had considerable experiences through the interaction between the external and internal environment and through the shared blood supply with its mother. This process is referred to as prenatal programming.
For example, presentation of an external stimulus like music or a nursery rhyme repeatedly and over a period of time to the fetus has shown that shortly after birth, the infant seems to recognize these stimuli. This is used as a way of investigating memory very early in development [1]. This indicates that a baby experiences several stimuli in-utero, remembers it and recognizes it after birth. These stimuli may influence an infant in several ways, physiologically and psychologically. Studies with fetal memory and prenatal programming have shown that certain traits and skills may start developing in-utero as a result of several maternal factors. Mothers who solve mathematical problems during pregnancy could increase the cognitive development of the fetus and lead to an intellectually gifted child. This study was undertaken to analyze various extensive researches and experiments conducted to understand this unique bond between the mother and her fetus and its implications on the development of various aspects of an individual's personality, preference and skills. Theories could then be postulated on probable and effective ways to modulate the fetal preferences in utero for future effective functioning of the individual to the highest level.

Materials and Methods

Relevant studies from indexed journals in PubMed, Google scholar and Science Direct were reviewed. Search words included prenatal programming, fetal preferences, maternal influence. All information was collated and analyzed.

Results and Discussion

Language

It is well understood that the adult brain is specialized in its response to native language. In 1996, a positron emission tomography study was undertaken to examine the activity of the brain in people while listening to stories in their original language, a second language learned after the age of seven, and an unknown third language. The native language stimulated several parts of the brain. Both the second and unknown languages elicited unique left-hemispheric activations in the phonological processing areas of the brain. These findings suggest that some parts of the brain are moulded as a result of early exposure to mother language, and that processing of a second language to which they have only had limited exposure later in life does not necessarily activate them [3].

The human brain is geared to language from the very beginning of development. Only a few days after birth, neonates have been discovered to respond differently to linguistic sounds than non-linguistic sounds. Human neonates manage their high amplitude sucking preferentially by listening to speech rather than complex non-speech analogues that regulated important spectral and temporal features of speech [4]. These findings back up the theory that human infants learn language with a preference for listening to speech.

The extent to which early prenatal language experience plays a role in establishing the neonates' 'neural tuning of language, is unknown. Neonates have the opportunity to learn about a number of the features of language while still in the womb. By twenty-six weeks of pregnancy, the peripheral auditory system of the foetus has matured, and the womb's features allow the majority of low-frequency noises (below 300 Hz) to be conveyed to the foetus' inner ear [5]. Low-frequency parts of language, such as pitch, some phonetic information, and some characteristics of rhythm, can be passed through the uterus, and the foetus can hear throughout the last trimester of pregnancy. From twenty-eight weeks onwards, consistent responses to auditory stimuli were seen. Experiments with animals and human studies have shown that sounds from outside the mother are weakened, but not by more than 30 decibels. Only thirty percent of phonetic information reaches the foetus, however intonation is nearly flawlessly conveyed to the amniotic sac [6]. There is currently a lot of evidence suggesting the foetus in utero learns the mother's voice or distinct patterns of sound from the same voice. Short-term auditory memory may also be present by the end of pregnancy. Foetuses also demonstrated the ability to distinguish between speech units such as syllables. Human babies exposed to repeated pairs of syllables had a considerable decrease in heart rate. A change in heart rate was observed when the sequence of the syllables in a pair was changed. This shows that the foetus can hear and remember language sounds before birth [7].

Newborn infants have been found to show preference for their mother's voice at birth [8]. In a study, pregnant women were instructed to read a certain piece aloud each day during the last six weeks of pregnancy. Their newborns were then tested and it was discovered that the sounds from previously recited passage was more reinforcing than the noises from a novel passage It was concluded that fetuses in the third trimester hear their mothers' speech, and this prenatal auditory experience can shape postnatal auditory preferences [9]. Yet another study proved that newborns born to monolingual moms prefer to listen to their original language than a foreign language [10]. These studies suggest that infants may have learned about the different properties of their native language while still in the womb.

A recent study of infants using neuroimaging technique of processing of speech and non-speech has supported the hypothesis that the experience of language might influence early neural specialization for processing certain aspects of language. However, this study was conducted on infants of four months of age, meaning that these infants had more experience with their native language than newborn infants [11].

In another study, the neonate's neural responses were studied while they were subjected to familiar and unfamiliar language, as well as to non-language stimuli. The location and patterns of the response of a neonate's brain to a familiar (the primary language exposed to in utero) versus an unfamiliar language was measured. When processing forward-played English sentences, neonates exhibit a rise in overall oxygenated hemoglobin across both hemispheres of the brain. In contrast, infants exposed to sentences of unfamiliar language showed a fall in oxygenated hemoglobin. These results provide proof that native language experienced prenatally, in utero, influences how a newborn's brain responds to language across brain regions, which are sensitive to processing of speech [12].

These studies indicate that infants begin learning the different components of language in utero and show a preference for their native language at the time of birth. These properties and preferences are carried by the individual and developed through the course of their lives.

Cognitive Development

There have been several studies that prove the link between maternal stress during her pregnancy and the impact of it on the child's developing emotional and behavioral mind. The physiological and neurochemical changes during maternal experiences seem to cause changes in the intrauterine environment thus generating the fetal response.

A study was performed on thirty-five women in the 28th to 40th week of pregnancy where each woman was verbally asked questions from a specialized mathematical questionnaire designed to be completed within a period of time. The blood flow in the fetal middle cerebral artery, the pulsatility index and the peak systolic velocity, was measured five times; first as an initial measurement, secondly after 10 minutes without mathematical activity, then 8 minutes after beginning the activity, fourthly at the end of activity and lastly 10 minutes after the activity was completed.

Comparing the results at the end the study showed that the fetal middle cerebral artery blood flow showed lower resistance during maternal mathematical activity thus proving that maternal brain activity and fetal blood flow are closely linked producing long and short-term changes in the fetus [2].

Flavor and Taste

Throughout human history, it has been assumed that what a woman goes through during pregnancy and nursing has an impact on her child's personality for the rest of her life. Stresses or shocks to the pregnant woman, such as poor diets, were thought to create mental imbalances in the child [13]. The rich history surrounding the choosing of wet nurses suggests that this idea extends to early postnatal life. It was believed that the lactating mothers or wet nurses, through their milk, provided the infant not only with nourishment but also characteristics of their personalities, such as their ideas, speech, intelligence and emotional qualities [14, 15].

According to recent research, newborns learn about the various foods consumed by their moms during pregnancy and nursing. Such encounters can skew people's perceptions of certain flavors and even "program" food preferences later in life. This may be a way in which culture-specific food preferences are likely initiated early in life. Flavors from the pregnant mother's diet are transmitted to the amniotic fluid and swallowed by the fetus. Consequently, the types of food consumed by pregnant women and, hence, the flavor principles of their culture may be experienced by the infants before they are first exposed to solid foods. The infants will experience some of these flavors later in the breast milk, which, like the amniotic fluid, contains flavors that reflect directly the foods, beverages and spices consumed by the mother [16].

Since dietary flavors are communicated to the amniotic fluid and help flavor it, studies suggest that the environment in which the human embryo lives, the amniotic sac, alters as a consequence of the mother's food choices. Researchers analyzed samples of amniotic fluid from ten pregnant women who were having a standard amniocentesis procedure. Five of the women were given placebo capsules 45 minutes before the procedure, whereas the other five were given garlic oil capsules. It was found that women who had taken garlic capsules had a stronger or more garlic-like odor than the other control group [17].

Maternal experiences with flavors like garlic leads to an increased preference and enjoyment for these flavors at birth and during weaning. It was demonstrated that exposure to dietary transmitted flavors such as garlic or anise in the amniotic fluid affects the facial, mouthing, and orienting responses of a newborn to those odors immediately postpartum [18, 19]. In a similar model of study it was also discovered that infants who were exposed to carrots prenatally via their mothers drinking carrot juice during pregnancy, enjoyed carrot-flavored cereal more than plain cereal, according to their mothers [20]. Hence, these early flavor experiences could lay the groundwork for later ethnic and cultural differences in cuisine. Prenatal and early postnatal exposure predisposes the young infant to react positively to a familiar flavor, easing the transition from fetal life to breastfeeding and the start of a solid food diet [21]. This may be how culture-specific flavor preferences are likely initiated early in life [20, 21].

Musical Mind

Preference for music usually evolves over time by exposure to different sounds, but this exposure can even begin in the womb, which aids in the learning of music and rhythms unique to one's culture. This begins in the third trimester of development as the acoustic environment in utero shapes the auditory system much earlier than other sensory systems such as vision. A twenty-five week old fetus has a developed and mature auditory system, which allows the hearing of intrauterine sounds such as their mother's heartbeats, breathing, digestion, and the maternal voice [22].

A study was conducted, where a five-minute recording of a piano lullaby at different decibels was played to 28-32 weeks pregnant women. An increase in heart rate in fetuses was seen with the highest decibel levels. For lower decibel level there seemed to be a response shift from acceleration to deceleration in heart rates, which proved that there was attention given to the stimulus [23].

In another study, 60 term fetuses were put in conditions where half were exposed to the voice recording of their mother and the other half to a female stranger's voice. The results of this showed an increase on fetal heart rate in response to their own mother's voice and a decrease in response to the stranger's voice proving that prenatal experiences influences fetal voice processing [24]. In another experiment it was observed that a fetuses seems to exhibit changes in their movements in response to a tune previously heard during the pregnancy thus proving fetal learning has taken place [25].

Findings also suggest that newborns can remember not only just the voice but also the general features of the rhyme such as pitch, tune and musical tempo also called as prosodic features [26].

The collection of studies done, underlines the fact that the musical brain starts its development months before birth. The exposure of the fetus to the maternal heartbeat and even musical input from the external environment in-utero does play an important role in the developing musical mind of the fetus and should be given more attention to as it can help in later development.

Accent

Prosodic features of sound like melody, rhythm, intensity are important for infant's language acquisition. There is strong evidence that infants are receptive to strong features of their native language even before they are able they are able to produce speech like babbling sounds or speak their very first words. Auditory learning begins as early as the third trimester as seen in studies regarding prenatal memory and studies carried out regarding frequency discrimination in fetus [27, 28]. The findings revealed that the fetus can distinguish between distinct frequencies and sounds better after 35 weeks of gestation [29]. While phonetic aspects of speech are blocked at the abdominal barrier, prosodic traits are preserved, making prosodic characteristics particularly crucial for the human baby [30]. As a result, an infant's prenatal perceptual liking for melodies show signs of early auditory learning processes in neonates [8, 9, 30].

Another investigation was carried out which focused on the potential effect of the surrounding language on babies' sound output. The melodic contours of French and German newborns' crying were analyzed to examine their intonation patterns. Growing (low to high) contours were preferred by French newborns, while dropping (high to low) were preferred by German ones. The findings suggest the newborns have not only memorized but also can replicate key intonations of their respective languages [31, 32]. Because babies' cries are already tuned to their original language, the study concluded that the newborns had most likely learnt the qualities of their mother tongue by listening to it prenatally,

with some early postnatal learning occurring within the first few days of life [33].

Hence, it is clear that prenatal and early postnatal experience with prosodic features of sound and language helps in the development of accent of an infant and in turn an adult.

Infant Temperament

Emotional and behavioral disorders are the result of a cascade of events, which can be attributed to prenatal, and childhood environment. Recent research has looked into the link between early-life adversity, specifically maternal prenatal stress, and later-life neurodevelopmental and health outcomes, such as emotional, behavioral, and cognitive psychopathology, stress physiology, brain plasticity, immune function, and chronic metabolic diseases [34-41].

Although exact mechanisms for intergenerational and transgenerational effects are unknown there have been studies wherein it was noted, that the levels of proopiomelanocortin and corticotropin-releasing hormone increase dramatically with progression of pregnancy. These hormones are important to fetal neurodevelopment and if altered due to stress can have long-term effects on the fetus. Evidence showed that these alterations could delay fetal nervous system maturation, diminish the stress response of the infant, damage mental development and bring about fearful behavior in the infant. Evidence collected show that the changes in stress hormone levels can result in emotional and cognitive disability [42]. It was found that during pregnancy and especially early in gestation, the psychobiological markers of stress resulted in a delay in fetal maturation, disrupted regulation of emotion and impaired cognitive performance, proving that maternal stress has long term effects on the fetus [43]. Research has shown a correlation between pregnancy-specific anxiety and infant temperamental negativity [44].

Infants who were exposed to the higher levels of maternal cortisol levels in earlier stages of gestation and also higher maternal stress during the whole pregnancy period were more likely to exhibit a slower behavioral recovery from the stress of the heel-stick procedure [45].

In the South London Child Development Study, mother-offspring dyads were examined for depression. When compared to non-exposed offspring, adult offspring exposed to maternal depression during pregnancy are three to four times more likely to have a depressive disorder [46].

Therefore, it can be inferred that there is a distinct connection between the prenatal maternal emotional state and the fetus which in turn causes long term changes in the emotional state of the child and future adult.

Conclusion

The bond between the mother and her child is a very strong one, affecting both of them psychologically and physiologically. The activities a mother indulges in while pregnant, the language and accent she speaks in, the food she eats and her emotional state during pregnancy, all help set the foundation for several traits and abilities in the fetus, which later develops throughout the course of a person's life.

We propose a long-term follow up, longitudinal study to study the effects on prenatal programming on the future skills of the individual. This would be effective in adding to the growing evidence that prenatal conditioning definitely impacts the individuals personality / intelligence and preferences. Based on the results theories could be postulated on probable and effective ways to modulate the fetal preferences in utero for future effective functioning of the individual.

Disclosure

The authors declare no conflict of interest

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