RESEARCH SUMMARY

Maternal speech shapes the cerebral frontotemporal network in neonates: a hemodynamic functional connectivity study

Uchida-Ota M, Arimitsu T, Tsuzuki D, Dan I, Ikeda K, Takahashi T and Minagawa Y. (2019)

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The development of healthy human infants in the first years of life is in many ways extraordinary. One of the most remarkable feats of that development is the acquisition of language skills. Psychologists have confirmed the common-sense view that babies whose primary care-givers – most often their mothers – spend the most time talking to them pick up these skills more quickly.

It is, perhaps, hardly surprising that infants respond more strongly to their mothers' voices than to others, because they are exposed to these sounds, and to their mothers' heartbeats, all the time they are in the womb. By the age of one month, a baby is able to distinguish his or her mother's voice from that of any other woman. Both before and after birth, an infant's auditory cortex – the parts of the temporal lobes on each side of the brain that process sound – is primed to develop in response to their mother's voice. Furthermore, numerous studies have found other brain regions in infants that respond more actively to their mothers' voices than to those of others. The strength of the 'voice-processing circuits' in the brain, in turn, have been correlated with social communication skills in older children, and this suggests that sustained exposure to maternal speech in infancy is likely to be particularly important in helping young children develop these essential skills.

However, there is still little precise information about how these brain regions interact when infants hear their mothers' speech, and how this differs from their response to other voices. In particular, the left and right temporal regions respond to different aspects of sound; the interactions between these regions and with the frontal cortex, which has been implicated in aspects of complex cognition, affect the higher-level processing and understanding of speech.

In order to gain insight into these complex processes, a group of Japanese scientists led by Yasuyo Minagawa from Keio University in Kanagawa investigated newborn infants' brain activity in response to voices using a technique called functional near-infrared spectroscopy (fNIRS). When a region of the brain is stimulated, blood flows into that area, causing an increase in the level of haemoglobin (the major component of red blood cells) that can be picked up and displayed on the spectrophotometer. This study involved 37 healthy, full-term infants with normal hearing between two and seven days old and their mothers, who were all monolingual Japanese speakers. Infants were exposed to short recordings of their mothers and female strangers speaking in the slow, rich way that is commonly used for talking to babies; each mother was used as the stranger for the next baby in the series. During the tests, the babies were all in a state known as ‘active sleep’. Haemoglobin measurements were made at 46 different positions in the front and side of the brain (frontal and temporal regions) using sensors attached to the babies’ scalps; the precise locations of these were determined by reducing the size of a detailed template produced from a year-old baby’s head to match the average head size of these newborn infants. This method has previously been used successfully to study brain development from birth to two years.

The data from the probes was used to calculate the level of both oxygenated (oxygen-carrying) and deoxygenated haemoglobin at each of the points in each baby’s brain. Typically, haemoglobin levels at many points rose in response to both the mother’ and the stranger’s speech, indicating increased activity in certain parts of the brain, and then dropped again following the stimulus. This is called a haemodynamic response. Oxygenated and deoxygenated haemoglobin levels were treated as separate measurements. The data was averaged over all the infants in the study, and the responses to the mothers’ and strangers’ voices were compared. These results were analysed to determine where responses were ‘in phase’, which suggested strong connections between those brain regions.This type of analysis is always harder in newborn babies with immature brain circuitry than in older children or adults.

In general, the researchers found significant changes in many haemoglobin levels in response to the maternal voices. This applied across the frontal cortex, both sides of the temporal cortex and other regions involved in the senses and in movement. The responses to the stranger’s voice were much weaker and mainly involved the oxygenated haemoglobin levels in the right side of the temporal cortex, which has been associated with processing sounds, learning and memory. In more detail, probes measuring the left and central frontal pole (at the very front of the brain), and the right middle temporal gyrus (on the side of the brain above the right ear) were among those that recorded strong changes in both haemoglobin levels in response to the mothers’ but not the strangers’ voices. Deoxygenated haemoglobin levels rose in response to the mothers’ voices in other parts of the frontal and temporal gyri, and haemoglobin levels in other parts of the temporal gyri rose more in response to the stranger’s speech. In general terms, the frontal region of the brain is implicated in higher reasoning, and the temporal gyri in processing emotions; this suggests that any early stimulation of these regions may help an infant develop reasoning and emotional control.

Looking at the phase data that determines connectivity between brain regions, the researchers again observed more correlation between signals and therefore more connectivity between regions in response to the mothers’ than to the strangers’ voices. Connections between the central frontal pole and the temporal areas, principally on the left side, and between the temporal areas and parts of the brain that are directly concerned with language, were observed in response to the mothers’ voices only.

Taking these results together, Minagawa and her co-workers suggest, first, that a mother’s speech induces far stronger changes to blood flow and, therefore, to brain

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activity in much of the frontal and temporal cortexes of her infant's brain than that of an unknown woman. Her speech also reinforces connectivity, particularly between the frontal region and the left temporal cortex. The left temporal region has previously been associated with language development in infants. This study is the first to link connectivity in this area to the response to speech in newborns, and it supports behavioural and physiological studies that have suggested that the mother's role in infant language acquisition is unique.

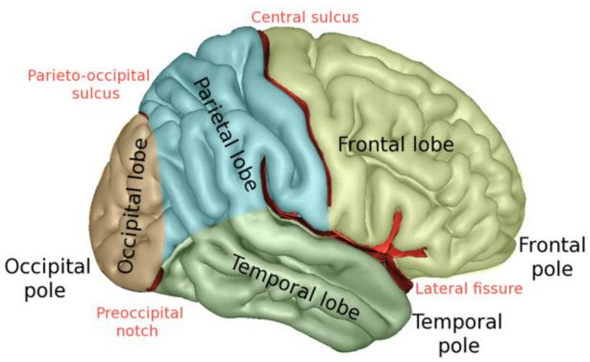
The researchers further suggest that sustained exposure to the mother's speech before birth may have primed this response for early development. They link this hypothesis to a report that the auditory cortex of extremely premature infants thickens as they are exposed to their mothers' voices during the first weeks of life outside the womb.

Connectivity between the frontal lobe and the right temporal cortex was found to be stimulated by both the maternal and the strangers' voices, although this was stronger and more complex in response to the mother's voice. This finding fits with the role of the right temporal cortex in voice identification and discrimination. Furthermore, the frontal cortex is known to have a role in processing positive emotion and reward, so infants hearing their mothers' voices will stimulate both these circuits. Finally, the researchers discussed the physiological mechanisms behind the speech response. This is a difficult area as relatively little is known about the physiology of such young infants, but what is known implies a distinctly different physiological response to the mother's familiar voice.

The researchers conclude that hearing the mother's voice can foster the development of strong connections between regions in the brain concerned with voice recognition and emotional processing, probably contributing to the development of higher cognitive function. There is good scientific evidence for the commonly held view that parents and carers – particularly mothers – who talk to their children will help them grow up to be happy and well-adjusted, and this is, perhaps, particularly true if they are young infants.

Dr Clare Sansom

Diagram of the main lobes of the brain, showing the frontal lobe and one of the temporal lobes at the side. The cortex is the outermost part of each lobe, and a gyrus is a ridge on the surface of the cortex.



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