

Fundamentals of language Acquisition

Prof. BIDISHA SOM

Dept. of HSS

IIT Guwahati

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Lecture 053

Lec 53: Brain development and its correlation with language development

Welcome back; this is lecture 3. In lectures 1 and 2, we looked at the structure of the human brain, brain mapping methods, and also, in the last lecture, we examined the major milestones in language acquisition during the very first couple of years of a child's life. In Lecture 3, we will look at the development of the human brain, important milestones, and their possible connections with the language acquisition stages. So, the neural development as well as the language development in the case of human beings has some correlations that have been proposed. So, first look at the development of the human brain. So, we will look at the prenatal and neonatal stages. So, when we talk about the prenatal stages, typically the division is in terms of the first, second, and third trimesters. So, we will stick to that kind of division. In the first trimester, some very important things happen regarding the development of the human brain. Of course, it is a long process, but for the sake of brevity, we will make it simpler.

By the end of the first trimester, the fundamental brain morphology and organization are already laid down. In fact, it is said that even before the mother knows she is carrying a child, the brain is already getting formed. So, virtually every neuron in the nervous system has been generated. So, there are the cells that will be generated, then they will be shifted, they will be transferred, then they will form the different regions and so on. So, the majority of the neurons are already generated. In the early stages of development, neurons will often co-express multiple transmitters and modulators, whereas single cells in the human mature brain exhibit much less diversity. So, what is very interesting in the case of the fetal brain is that it already creates a large number of neurons. Eventually, they will be pruned. All of those neurons will not be necessary later on. This will be cut down.

This will be cleaned, and so on. the majority of the neurons are created, however. They are also busy doing multiple things, which will not be reflected in the adult brain. So, initially, neurons will have what is called co-expression. They will co-express multiple transmitters and modulators. whereas single cells in the mature brain do not do that, they exhibit much less diversity. So, the brain not only has a large number of cells, but it also shows a lot of diversity; however, what is not yet fully in place is the tail of the distribution of the last layer of the isocortex, the external granular layer of the cerebellum, the hippocampal dentate gyrus, and the olfactory bulb. So, certain parts of the brain are not yet developed, but the majority of the cells, the majority of the neurons are already generated. In the second trimester, this is the period during which the basic wiring of the brain takes place. First, the neurons are created; then the wiring happens.

So, the large patterns of connectivity will emerge at this stage. So, the second trimester typically gives us the connectivity developing between different neural regions, including the isocortex. From a developmental point of view, one of the most important events is the establishment of connections from the thalamus to all regions of the isocortex. In the beginning of this module, we looked at the structure of the brain, noting that certain layers in the cortex are connected; there is a connection from the cortex to the thalamus and then from the thalamus to input and output, creating a connection that develops in the second trimester itself. And then, intracortical pathways also develop. Intracortical pathways, as the name suggests, are the connections from one cortical region to another cortical region. So, that also begins to establish the mature connectivity pattern. What it means is that the kind of connectivity pattern that you see in the mature brain already starts in the second trimester of the fetus. Now, these connections are set up in the second trimester in a pattern that resembles the adult pattern very much. So, a lot of work is actually required, so you can imagine how quick and how fast the entire process of creating the brain is.

So, animal studies show that visual, somatosensory, auditory, and limbic areas of the cortex all receive projections fairly exclusively from those thalamic nuclei that will project to them in adulthood. Basically, the connection between the thalamus and the cortical regions that will be visible in an adult brain is already in place during this time. The corpus callosum makes its first appearance around post-conceptual day 90, which is when the corpus callosum appears. Connections between the areas of cortex and their corresponding cortex on the other side, called homotopic connections, also built up over the following months. So, rapid construction basically goes on during this time.

During this time, another very important thing happens, which is called apoptosis. So,

this is basically a particular kind of regressive event called apoptotic neuronal death. Now, one might wonder why neurons die. Neuronal death is the death of neurons. So, in the very beginning of life, this is the second trimester when, in the first trimester, neuronal generation has already happened; lots of neuronal cells have been created; actually, they have been created in surplus. So that is why. So, this is programmed this way; it does not happen in a haphazard way. This is programmed in such a way that the unnecessary or excess redundant neurons will die; that is what apoptosis refers to. This kind of developmental cell death usually occurs in close association with the establishment of major axon pathways between regions. So, as the connections are being developed, there are some redundant axons and some redundant connections that are not necessary; those will die. So, this is part of basically removing everything that is redundant.

So the removal of excess errors of axonal connections is also part of this kind of neural death. For example, the retina establishes its connections with subcortical targets in the third month post-conception in humans. It reaches the peak number of axons in the optic nerve about a month later. By the end of month 5, retinal ganglion cell loss is over, removing as much as 80 percent of the originally generated cell population. So, this is what we mean: in the first trimester, cell generation happens on a very large scale, and many of those cells will eventually not be necessary; they will not be needed; they are excess; they will die. That is the process. Then another important aspect around this time is what is called self-instruction. The second trimester is also the period in which something akin to learning or self-instruction begins. So, self-instruction is based on whatever is happening within the system itself because this is still in utero; it is not outside in the world. So, there is no way to learn anything from the environment, but as the process goes on, some learning happens within the system. That is what is called self-instruction.

It is a process of activity-dependent self-organization of the nervous system that is self-instruction. In utero, this means the activity of the body itself or the intrinsic circuitry of the nervous system. So, as things are developing, whatever is happening there is causing the system to learn something on its own. Activity-dependent organization occupies the middle ground in the nature-nurture debate. That is why this aspect is very crucial, because remember our nature part of the debate says that the human brain, you know, comes pre-processed; it's all there from the very beginning. We do not need to do anything. Nurture, on the other hand, says that environmental input play a major role in language acquisition. Now, because we know that something called self-instruction happens, this is kind of a middle path between nature and nurture, where some of the same mechanisms that will be used later for learning from the outside world are used in utero to set up this basic function. So, response to the correlations in the input which we

will eventually learn after birth we will learn we will take input from the outside world that mechanism gets fine tuned during this time. So, the basic infrastructure is created this time.

So, the basic functional architecture of the brain was created around that time. In utero, some of this organizational activity may be imposed by the system itself. By the beginning of the seventh month of gestation, a remarkably large number of neural events are complete in the third trimester. You can see how many things happen in between. So, reciprocal connectivity from higher-order cortical areas to primary areas has also begun around this very time. Pathways exhibit the initial processes of myelination as well. Myelination refers to the creation of the myelin sheath on the neuronal structure. So, that is connected to the higher functioning capacity of the neuron and the network. So, that also starts around the third trimester. Large descending pathways from the cortex area are also in the process of development. Aside from the more obvious role of descending pathways in motor control, the appearance of descending pathways also means that the brain has started to talk back to its input regions. So, the brain has, of course, various regions. So, the sensory input goes from the sensory apparatus to one particular region in the brain, and from there it goes further to the cortex. So, the cortical region is not where the input comes in first. That is what we mean by talking back to the input regions, the input region, and then the cortical region.

So, there is a connection between these two that begins to happen around this time, the third trimester. So, a form of interaction is found in all sensory as well as motor systems. So, the input from the visual apparatus goes to the first domain, and from there it goes to the cortical region, visual cortex, and so on. So, that is what we mean. And finally, in the 8th and 9th months, a massive and coordinated birth of synaptic connections begins in the isocortex and the related structures. So, the synapse, as all of you know, is the connection between neurons. So, synaptogenesis happens. This coincides with birth; just before birth, a massive generation of synaptic connections begins. So, when the babies are born, a nervous system with all its working components in place and organized is present. So, the machine is, kind of the basic architecture is already in place; all cells are generated, and all major incoming sensory pathways are in place. They have already undergone so many processes. So, all major incoming sensory pathways are created, all the working components are in place, and they have already gone through a period of refinement of their total number of cells because we have seen that neural death and pruning also happen before birth. So, the refinement has already happened, connections and topographic organization are also done, intracortical and connectional pathways are well developed, though output pathways are still lagging behind, but the input pathways are better established around the time the baby is born. So, in essence, what it means is that

the big cortical regions, specifically the primary sensory and motor regions, are the most important cortical regions; they already have their adult input and topography. So, the adult brain structure has developed at this point when the child is born; in terms of these major areas, they resemble the adult brain; that is what this means. Though we do not yet know if the multiple sub-areas described for the primary cortex have sorted themselves out. So, broadly the areas are already there, but the more subtle multiple sub-areas within this are already in place or not, that is not very clear. Thus, the brain is up and running at birth, ready to learn. So, this is primarily because many things are already in place. Postnatal changes have many important factors that happen; one of the most important is, of course, myelination. Myelination refers to the increase in the fatty sheath that surrounds the neuronal pathways. There is a layer of fatty sheath, a covering of some sort that occurs there, and this surrounds the neural pathways. So, this process increases the efficiency of the information transmission between neurons. So, from one neuron to another through the network, if after myelination the process becomes more efficient. In the central nervous system, sensory areas tend to myelinate earlier than the motor area.

So, sensory before the motor. This has very important implications. For example, this has been cited as a possible reason why the disparity between language comprehension and production is very common in the case of humans. So, for example, language we have seen in word production and word comprehension. So, word comprehension starts much earlier than word production. This is probably because the sensory areas get myelinated first and the motor areas get myelinated later; that is the idea.

Intracortical association areas are known to myelinate last and continue to myelinate at least in the second decade of life. So, this is not a very short-term process; it goes on for a very long time. So, starting from the very beginning of postnatal life until the second decade of life. So, of course, the sensory areas are developed first, followed by the motor areas, followed by the other intracortical association areas. Unmyelinated connections in the young human brain are still capable of transmitting information.

It is not as if, because the entire brain is not myelinated at that stage, they will not be able to carry out the processes or transmit the information. That is not how it works, but with myelination, it becomes more efficient. So, additions to the myelin sheath may increase efficiency, though they do not create efficiency that needs to be kept in mind; however, they cannot be the primary causal factor in the brain's organization of language or any other cognitive processes. Now, till here, what are the major changes in terms of the neural structure and the language? Regional connectivity of the isocortex begins in the second trimester and, although completed postnatally, it starts in the second trimester; however, it bears no direct obvious relationship with language activity, except in a permissive sense, as has been proposed. Even though the regional connections are already

in place, they may not have any direct impact; however, they provide a facility, facilitate, and create a permissive scenario for language to develop, though they may not really create it.

A mature reciprocal pattern from the secondary to primary visual cortex is established somewhere between 4 months and 2 years in developing humans. Myelination brackets language acquisition only in the most global sense. So, myelination, though it is a very important factor in the efficiency of information routing, creates a permissive environment just like any of the previous ones that I have discussed. So, it creates a facilitation in a global sense because it takes place somewhere between gestation and adulthood. So, it is a large time frame that it facilitates; that is the idea.

So, there is no direct impact of the changes in the neuronal structure with respect to language that we have seen so far. However, what happens after this is very important that is our synapses. Synapses are what? They are chemical junctions between neurons. It is a pathway for information sharing. These synapses are easily recognizable and countable, and as a result, they have been studied in terms of neural signaling.

The most commonly studied synapse is the chemical type of synapse. There are many other kinds as well. So, it is more visible; it is easily countable. This is why it has been studied most with respect to various kinds of mental function. But there are also other kinds of synapses. For example, there can be direct electrical coupling between cells. This is particularly prominent in early development. Cells can communicate through the release of gases as well. Most notably, the nitric oxide also alters the extracellular milieu of the neurons surrounding them. So, there are many different ideas here: there is more than one way of communication across cells, across neurons, and the networks. Synapse is, of course, one of the most important and most visible ones, but these are the other different kinds. Now, the idea of synaptogenesis is very important for neural development. This occurs in the critical time window of early language development: the genesis of the synapse. So, first the cells are created, then the creation of the synapse happens in the last part of the prenatal stage, and it continues for some time, and that is why it is very important. So, it seems optimally placed for the rapid statistical learning that infants show in both the visual and auditory realms during this time. Synaptogenesis means the creation of synapses; therefore, synapse elimination also happens around the same time. So, synaptogenesis and synapse elimination co-occur during most of early postnatal development, and they also occur throughout life. So, newer connections are always created; the idea of the plasticity of the brain is basically, to a large extent, based on this. So, your new experiences create new kinds of networks, new kinds of connections.

So, as a result, synaptogenesis is a lifelong affair. Normally, this is a kind of universal process that, in the early part of life, particularly in the early part of postnatal life, a large number of synaptogenesis is typically visible. and that also co-occurs with the major milestones of language development. There are some interesting features, however, that we have to be careful about regarding synaptogenesis and elimination within the perinatal period that seem quite related to language acquisition. So, synaptogenesis and synapse elimination co-occur over most of early postnatal development, and of course, they continue throughout your life, and there seem to be certain interesting features associated with this as well. So, synaptic connectivity is the primary means by which knowledge is represented in the brain.

So, if we ask somebody, if you ask a neuroscientist what knowledge is, how knowledge is represented in the brain, and in what form. The main idea is that it is stored in the form of synapses, meaning in the kind of connections that we have created in the brain that represent that knowledge. So, for example, we know that for every language, many languages have this idea that when we say prices are going up, basically we mean they are higher now. So, "up is more" is a connection that language makes in the neural structure, as well as a connection between these two disparate things. So, these connections are, and this knowledge is neurally represented in terms of the synapse that is created and the connections that are made. This is what we mean when we say that knowledge is represented in the brain in terms of synapses. This knowledge can be innate, set up independently of experiences; it can be learned, set up by experiences, or somewhere in between, as in the above-mentioned case of the prenatal activity dependence that we have seen before. So, this is the reason for interest in the role of synaptogenesis and synaptic connectivity in behavioral development because this correlates with so many other things. The number of synapses is often thought of as an index of the amount and complexity of information transfer in a structure.

However, there is one thing that you have to be careful about. There is a syndrome called sudden infant death syndrome (SIDS). This is associated with an excess number of persisting synapses in the medulla. So, even though higher number of synapses is typically taken as an indicator of better or more complex transfer of information. Sometimes, it may not be a good thing at all, as is the case with sudden infant death syndrome, which is typically caused by persistent synapses in a particular area of the brain. Then, metabolism and synaptogenesis, there is an influential study using PET, or positron emission tomography. The study of human infants was carried out in the resting stage. The resting stage is when you are not doing anything, when you are resting. The brain is not actively doing anything; it is not speaking, not playing, not watching

anything, but rather in a resting stage. So, they are either asleep, or they are sedated. In this study, it showed a marked increase in frontal lobe metabolism starting between 9 and 12 months of postnatal age. Now, this is the age that is also crucial in terms of language development stages.

Now, this was a resting stage, as a result of which this high metabolism was not a response to any kind of stimulus or task. So, the authors and scholars suggested that the sharp increase in glucose metabolism might be caused by a burst in synaptogenesis. So, if new synapses are being created, you see the reflection in terms of glucose metabolism. Now, this reflects a structure-to-function gradient, where more synapses mean more glucose metabolism. Now, the reaction as a result of which this has also been studied in terms of correlation or co-occurrence of this metabolism with a higher synaptogenesis, as well as the correlation with the language-related developments.

So, based on this kind of findings, Bates et al. proposed a four layered connection interaction between the neural events and language learning. They call it readiness for learning, experience-driven changes, rethinking two postnatal correlates of language, and the sensitive period. Readiness for learning: we have already seen that the infant brain at birth is up and running; the connections are already in place. So, it is ready to learn that the idea behind this particular area, particular stage of the correlation between language and neural activities. This is followed by the experience-driven changes, which is also something we have already seen. Learning itself contributes to the structure of the developing brain in infants as well as in adults. We learn throughout our lives, make new connections, and the brain creates new connections, neuronal connections, synapses, and so on. This is more evident in the case of infants. So, various experiences are found to profoundly impact synaptogenesis, though it may not be in the first part. We have seen the first part of synaptogenesis, which happens just before birth in the eighth and ninth months of gestation, but the later parts of synaptogenesis may be dependent on experiences.

So, these are experience-driven changes. So, findings from many studies, in fact, post-mortem analyses of adult human brains, have shown a correlation between high levels of education and increased dendritic branching in Wernicke's area. So, this is an example of experiences changing the neuronal structure itself. So, there is a direct correlation between experiences and neural changes. And then, with respect to the postnatal correlates of language, in relation to various kinds of neuronal structures. So, changes in the frontal lobe activity seem to coincide with the 8 to 10 months of watershed that we have already discussed. 8 to 10 months is the time window when a lot of activity in the

frontal lobe occurs, metabolism gets higher, which is taken as a result of synaptogenesis, and this is also the watershed moment where linguistic behavior and other changes happen. So, changes in synaptic density seem to coincide with bursts in vocabulary and grammar between 16 and 30 months. So, there is a parallel that has been proposed. So, these parallels between language bursts and the synaptic burst may represent a mutually beneficial relationship, but it may not be a very crucial and direct relationship of cause and effect.

That is not what they are proposing. They are saying that there seems to be a mutually beneficial kind of relationship. Of course, more data is awaited; more work is going on in this domain. And last but not least, the sensitive period. So, the critical period for language is often used to distinguish between child language acquisition and second language acquisition or adult language acquisition. So, the idea of the critical period is very crucial there, as we all know. Under controlled learning conditions, it has been found in a very old study ('78) that adults and children perform at a similar level in the early stages of second language acquisition. However, later stages of language learning may show differences. So, a child may continue at the same speed, but an adult's learning abilities may get fossilized as they have talked about it. So, these kinds of results do reflect and support the idea that there is an age-related component in terms of the plasticity of language learning. However, if you look at a deeper level, there are some differences. For example, not all linguistic abilities are equally affected by sensitive periods. Some aspects of language, yes, but not everything. For example, the earlier decline is reported for accent-free phonetic production as opposed to the various other kinds of grammatical structures. So, there are different kinds of time windows for different types of linguistic abilities. So, accent-free production is one, but grammatical structure might have a different time window.

Even within grammatical structures, some of the structures can be learned even later, but some structures seem to be very difficult and difficult to learn after the sensitive period. So, this points to a series of gradients rather than a very strict time window, and these gradients might vary with the task difficulty level. So, the scientific understanding of this period is still advancing; we still do not have the final word. Data now suggest that an adult's difficulty in learning a second language is affected not only by maturation but also by learning itself, because learning itself also changes the neural circuitry, as we have just seen. So, based on all these findings, Kuhl had proposed the native language neural commitment hypothesis.

In this, they explored the relationship between the transition in phonetic perception and later language learning. This examines the critical test stemming from the native language neural commitment idea. The hypothesis is that the initial native language experience produces changes in the neural architecture and connections that reflect the pattern regularities of what is imbibed in the ambient speech. So, the native language that the child is surrounded by creates a certain kind of neuronal structure that is, you know, committed to the native language. So, the native language and the corresponding neural architectures are what we are talking about here. So, the brain's neural commitment to native language pattern has a bidirectional effect. Neural coding facilitates the detection of more complex language units. So, first the neural coding happens because of the learning from the ambient language, and it facilitates the learning of more complex words; simultaneously, it also reduces attention to the alternate patterns, such as those of a non-native language. So, while they are reinforcing the native language structures and the differentiations, at the same time they are also making them; this is why we see the perceptual narrowing. So, the reduced attention to the alternate possibilities that are part of, let us say, all the other languages, not the native language.

So, this works in a bidirectional manner. So, this is also a developing domain; of course, there is new evidence coming up. But this is another important hypothesis in this domain where we are looking at language development with respect to the neural correlates across different domains. So, not only the different stages but also what happens during those stages and what probably gives rise to the neuronal structure. So, there is a two-way traffic. The language structure making changes, the ambient language making changes in the neural structure and simultaneously various kinds of neural, various milestones of neural development having a, probably having a correlation with the language related development that we see in the infants, in infancy, the beginning, the first couple of years of the child's life. So, this is where we end our lecture. Thank you.