Psychology of Bilingualism and Multilingualism

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Week - 06
Lecture – 26

Hello and welcome to the course introduction to the psychology of bilingualism and multilingualism. I am Dr. Ark Verma, an assistant professor of psychology at the department of cognitive sciences at IIT Kanpur. In this week I will talk to you about the bilingual or the multilingual brain. We have seen so far that the language system of bilinguals is slightly different from that of monolinguals and the question that can be asked here is that whether the tasks that the bilinguals have to handle are the neural structures responsible for completing those tasks such as acquisition of language, production and comprehension and also control of the languages in bilinguals and multilinguals are the neural structures same for both for monolinguals and bilingual individuals or are they different neural structures. We have seen by now ample evidence of the fact that a bilingual must constantly coordinate the functioning of their two or more languages for both production and comprehension and also that they require an elaborate system of control for managing these two languages.

So before we sort of go into the detail of the bilingual brain, I would like to recap a little bit for you about the basic principles of organization of the brain which I have elsewhere covered in the course on introduction to brain and behavior. Now it is common knowledge that the human brain is divided into two cerebral hemispheres separated by the longitudinal fissure and connected by the corpus callosum which is actually composed of a myelinated axons of neurons that cross over between the two sides. The corpus callosum actually serves as the site providing interchange or exchange of information between the two hemispheres. Also we note that the two hemispheres of the brain are not exactly identical in both structure and in function and that the most prominent functional asymmetry that is observed between the two hemispheres is that the left hemisphere mediates language functions and the right hemisphere mediates visual spatial functions.

However, the functional asymmetry of the two hemispheres does not imply that the left hemisphere solely takes care of language related functions or that the right hemisphere solely takes care of the visual spatial functions or emotions, colors, etc. etc. However, when researchers have sought to investigate the bilingual brain, two major types of questions have surfaced mainly. For instance, whether the regions of the brain subserving language functions for monolinguals are the same and they function in the same way for bi and monolinguals too. Remember, when a monolingual is actually going through the stages of production, say for example conceptualization, formulation, lexical selection, articulation and so on, they actually do not have any conflict, they actually have just one language system and therefore it is in some sense you could say rather smooth that you can basically pick up the contents from one language and go with it.

Even within that you have seen that there are phenomena like lexical selection, competition between members of the same language and so on, which you can see that actually get multiplied when we are talking about a bilingual or a multilingual. So are the brain regions that are responsible for conceptualization, formulation and articulation or say for example which are responsible for comprehension in monolinguals, are these the same structures that are responsible for bi and multilinguals as well? Also an important aspect of, an important question that is asked in reference to bilinguals and multilinguals is that what are the areas of the brain that are actually enabling the bi and multilinguals to coordinate between their two languages? More specifically are these regions that are involved in language control in bilinguals and multilinguals also the same regions that are involved in domain general cognitive control as well? For example, in situations where we might have to handle two tasks at the same time, those kind of task switching, those kind of coordination between two tasks, are they pretty much similar to the coordination that is required by bilinguals or multilinguals to manage between their two languages? Before we go on to understand these questions and before we go on to sort of you know look at research studies on these questions, let us look at some of the methods that have been used for investigating the brain. Now functions of the brain have traditionally been looked at through two kinds of studies. First are clinical studies with patients having language disorders caused by brain damage let's say due to stroke, injury or some kind of a neurodegenerative disease such as Alzheimer's. Also a lot of insight about you know the functioning of the brain comes from non-invasive imaging methods such as electroencephalography, neuroimaging etc which allow the scientists to study the neural processes of the working brain in response to stimulation.

Deficits in language comprehension or production are mainly caused by brain damage which is collectively known as aphasia. Initial studies by you know Paul Broca and Carl Wernicke actually indicated that the lesions in specific parts of the brain such as the Broca's area which is roughly around the infero-frontal cortex and Wernick's area which is roughly around the temporal cortex lead to specific deficiencies in production and comprehension. However, researchers have you know resorted to use the non-invasive imaging techniques to observe the workings of the brain which are referred to as structural imaging techniques during which the anatomical structure of the brain can be revealed while they're actually responding to carefully designed stimuli. Let's look at some of these methods briefly. Computerized tomography.

Now computerized tomography is an advanced application of the well-used X-ray methodology which is used to reconstruct three-dimensional images of brain structures from two-dimensional images produced by the X-ray. Typically, what happens is that this technique builds upon the fact that the radiation absorbed by the neural tissue differs you know with respect to its density and distribution across the brain and it is this information that the CT scan actually uses to construct a three-dimensional image of the brain. It allows us some you know a great insight into the anatomical structure of the brain and accordingly lets us know if there are any lesions or any you know injuries in the brain which can actually be seen through this kind of an X-ray. Magnetic resonance imaging or MRI. Magnetic resonance imaging or MRI is actually a technique that taps into the magnetic property of the tissue by temporarily altering the orientation of the hydrogen atoms present in the tissue through a strong magnetic field.

You know this is then detectable when the atoms return to their original position and the basically can be captured by the MRI scanner. Now the specific characteristics of these magnetic fields actually vary with the distribution of the hydrogen atoms in various brain tissues which allows you know for the detection of structures in the brain. Thus MRI offers a much better spatial resolution than the CT scan methodology. For instance, MRI scans are able to provide images of brain structures that are less than one millimeter apart as opposed to CT scans which can only provide you know images of structures that are about five millimeters apart. Further MRI scans are able to distinguish between gray matter and white matter which also tell us important you know insights about you know which aspects of the neurons are actually involved in neural activity and which are not.

Another very interesting technique that is available to the researchers is called the diffusion tensor imaging which is a technique that utilizes the MRI scanner to provide images of white matter tracks in the brain and give us some insights about the functional connectivity in the brain. It is able to measure the density and motion of you know water in the axons as well. Now electroencephalography or event related potentials. ERPs are the electrical activity in the brain that are modulated by sensory motor and motor and cognitive events. Essentially what happens is that the EEG actually records the electrical activity of thousands of neurons in the cortex using a number of electrodes that are placed on some on an individual's scalp.

More specifically a reference electrode is placed at some distance from these electrodes and the difference between the you know reference electrodes and these scalp electrodes is actually mentioned. This is measured. This is actually referred to as the EEG. Now at some points what might happen is that the specific stimulus may be presented to the individual on whose you know scalp these electrodes are placed and there could be a small voltage change in response to the stimulus. Now on a single trial the presentation of this you know small stimulus could actually would actually lead to only a very small electrical change or voltage difference and therefore EEG researchers actually need to present repetitions several repetitions of these events which will have to be later averaged together to tell us about what kind of electrical activity happens pertaining to what kind of stimulus manipulation with these participants.

EEG has a very good temporal resolution because it captures the electrical activity of the neurons in real time and can actually tell us about you know the happenings on in the brain with respect to particular stimulus at a very you know highly resolved time scale. So far we have seen that you know MRI has a better spatial resolution whereas EEG has a better temporal resolution. One technique that has the best of both worlds is referred to as the magnetic encephalography. Now MEG is actually a process very similar to the EEG but it actually measures the magnetic correlates of the electrical activity in the neurons. Many specific stimuli are presented.

More precisely in MEG studies the magnetic field aroused by an individual stimulus is again too small and hence the same is averaged over a number of trials just like it happens in ERP. Interestingly the MEG technique has a very good spatial resolution as well as a very good temporal resolution and it can allow us insights into what is happening in the brain when a particular kind of stimulus is presented and at what time course. For example, if I am presenting to you a written word the MEG may be able to tell me which parts of my brain are responsible for deciphering that word stimulus and at what time scale. Another very distinct technique albeit slightly less favoured is called positron emission tomography. The positron emission tomography is basically a technique that builds upon the flow of the blood from one part of the brain to the other.

More precisely researchers actually need to inject a small amount of water tagged with a radioactive isotope in the bloodstream while the participant is actually performing a cognitive task. Now during this cognitive task what happens is that most often a radioactive form of oxygen that is oxygen 15 is you know is used which actually accumulates in the different areas of the brain in direct proportion to the amount of blood supply that is reaching these areas of the brain. Once these you know isotopes actually have reached the different areas of the brain the nuclei of these oxygen 15 isotopes are you know they start emitting a positron from their nucleus during decay. This positron collides with an electron in the blood and is converted into two photons which move in opposite directions. These photons are actually detected by the MRI by the PET camera.

In a sense basically it is this collision between the positron and the electron from the blood that actually allow us a hint of as to where the maximum activity in the brain is happening at any given point in time. So the collision of the positron and the electron along with the simultaneous detection of these photons may happen several times per minute and therefore are counted and in that sense are used to provide an indirect measure of the neural activity in that brain region. And the critical dependent measure in the PET is commonly referred to as the regional cerebral blood flow which basically provides us an indirect way of you know judging the distribution of blood supply in the brain. Now the assumption the underlying assumption in this technique is that the areas of the brain that will be involved in the given cognitive task such as viewing a picture of a face or a house or reading a word actually you know the areas of the brain that are involved in these tasks will receive the maximum blood flow and a maximum blood supply. So it is and these sites the photons will be detected and in that is how this technique will allow us to you know mark that okay region X Y and Z was involved in task A region A region C were involved in task B.

However since it takes close to 60 seconds for the PET signal to build up and the cognitive functions as we know operate at a much you know faster time scale of milliseconds the temporal resolution of the PET method is actually very poor. However, its spatial resolution is very good because it as you see because it is depending on the blood supply to areas of the brain and it is capable of you know providing us with you know better insight into areas of the brain that are involved in this activity. PET studies typically compare the changes in the medical metabolical activity in the brain between a baseline condition let's say when no task is given and an experimental condition where the individual is actually performing a particular task by subtracting the activation patterns observed in these two conditions the PET researchers are able to identify which areas of the brain are responsible for which particular task. Say for example when I am measuring PET activity when you are not being shown any picture or let's say a blank screen and then I am comparing this to when you are seeing a picture of a house on the screen and I subtract these two what remains is the brain activity that is contingent to presentation of the house and therefore I could actually make a reasonable assumption that the brain activity that I have observed as a result of the subtraction is contingent to my processing of the house. A very similar technique which is also used heavily by researchers around the world is called the functional magnetic resonance imaging technique.

The functional magnetic resonance imaging technique or the fMRI as we call it follows also follows the principle of hemodynamic imaging imaging of the blood flow it is non-inversive and therefore is preferred over the PET methodology. What really happens in fMRI is that it utilizes the physical properties of the blood of the elements in the blood specifically the magnetic properties of the iron holding hemoglobin you know in the blood cells and it uses MRI scanners to track the same. In more detail what happens is that hemoglobin transports oxygen through the blood and oxygen is absorbed by the active areas of the brain thus deoxygenating the blood when the blood gets deoxygenated this and deoxygenated blood has paramagnetic properties which can be tracked by the fMRI equipment. So the exact measure that we are actually looking for or the exact dependent measure is the ratio between the oxygenated to the deoxygenated blood in different brain areas which is referred to as the blood oxygen level dependent response or the bold response. The bold response is typically higher in the areas of the brain that have been recently active in or actively engaged in a given cognitive task.

At this point I'll just sort of wanted to present to you a very broad you know anatomical overview of the brain as you know taken in the Groot's book you can see that this is the superior frontal gyrus middle frontal inferior frontal gyrus superior temporal middle temporal inferior temporal gyrus pre central gyrus post central gyrus and supra marginal gyrus and so these are the anatomical gyri which you will hear me speaking about as we go ahead and discuss the studies in more detail. Similarly, I will also be talking about the views of the brain dorsal area or superior area, rostral area or anterior area, caudal area or posterior area and so on and so forth. So please remember these you know jargon when we are talking about these things in more detail in the upcoming lectures. Thank you for now I will talk to you in more detail about the bilingual brain in the next lecture. Thank you.