**Language, Culture and Cognition: An Introduction**

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**Module - 08**
**Part - 02**
**Lecture - 19**
**Role of executive function in language processing**

Welcome to the part 2 of module 8. In part 1 of this module we have discussed in detail about the executive control or the cognitive control mechanism in humans. We have looked at how the different brain regions are responsible for controlling various sort of various kinds of human output in case of, in terms of more sensory motor output as well as linguistic output. And we have had a detailed discussion on various aspects of it.

Now, in this part, we will look at those relationship of those cognitive control networks with respect to language functions, as in, how various types of language processing are interrelated with the control cognitive control mechanism, in terms of the brain regions that are responsible for those control systems in place.

So, the structure of this part is like this. First, we will discuss the relationship between language processing and cognitive control or executive control mechanism, through various experimental research, various data from experimental research spanning various types of language processing.

And then we will go ahead on the assumption that general purpose brain function are related to language related processing as well. And then there is also a controversial, this is not entirely a straight jacketed idea, there are controversies there are debates on this. So, the counterview of this assumption will also be discussed.

Now, when we look at language processing with respect to executive control, we will take various types within that. So, we will start with sentence processing, word processing, bilingual advantage and so on.

So, let us start. So, the language and executive control link has been established by a number of, great number of research output primarily from the neuroscientific experiments. So, recent findings have suggested that mechanisms of executive control may

be probably involved in language processing in these three domains, domains of sentence processing, word production and as well as bilingual language processing.

So, these are the three domains that have been extensively researched on, extensively worked upon and this is the data that we will look at.

So, this linking was possible due to a large amount of data coming in primarily from neuroscience experiments as we have seen before as well, in the in part 1 of this module. So, that the large number of data that we are talking about here, that we are referring to here come from neuroscience.

So, these findings point out that brain areas that are responsible for general purpose executive control are also activated during language tasks. So, this is the fundamental thing. In terms of executive control mechanism, we have seen that there are certain brain areas we have also talked about those brain areas. So, those certain brain areas are responsible for general purpose cognitive control mechanism in human beings.

Now, when we link this function to the language processing task, the primary objective is to find whether those brain regions are activated while processing language. While processing language in conditions where there is some kind of a conflict, some kind of a competition, which needs to be resolved. Remember we talked about cognitive control which is activated when there is a conflict.

So, conflict monitoring and conflict resolution are the fundamental aspects of cognitive control and executive control. So, this is what we are looking at, whether the same regions are activated by language processing when there is a conflict. So, what are those areas? we have already seen, but just to remind you these are the left inferior frontal gyrus and then dorsal medial PFC as well as dorsal anterior. So, the ACC, dACC dorsal ACC we have already looked at these areas.

So, now this means that the fundamental thing that we are driving trying to drive home here is the mechanisms of executive control that are recruited to resolve competition between representations in language; so, it can be phonological representation, it can be semantic representation, syntactic representation and so on and so forth. So, when there are competitions between different representations, between different linguistic this representations in language processing, it may be similar to those that are recruited to

resolve competition between perception and attentional responsible representations as well. So, what are we looking at here? We are looking at the competitions that may arise during language processing, be it in any domain of language processing are we looking at the same brain regions or not, is the question.

So, in perception and attention the general cognitive executive functions are mediated by a network of frontal, parietal and sub-cortical structures, which we have already seen which are those areas.

So, now let us move on with some data. This area of research is vast, it is really very rich. So, there are number of groups working on these even you know, nuances on these in each of these domains. So, we will discuss only some representative experiments, but I will include a lot more references in the list for you to read. So, one of the, one of the very well cited and very well known studies looked at this particular question as to whether there is a similarity in conflict resolution in linguistic scenario with respect to the non-linguistic scenario.

So, this study by Ye and Zhou explored what to what extent the neural correlates of control processes in sentence processing are similar to those in perception and attention. So, they used a fMRI study along with a behavioural study. In the behavioural task, they had a sentence comprehension task, the flanker task and a color-word Stroop task.

Color-word Stroop task and flanker task both are designed to look at conflict resolution mechanism. And sentence comprehension task is the linguistic task thereby they can compare whether the sentence comprehension task had anything to do, any similarities to the non linguistic task. The tasks were carried out on the same group of participants.

The linguistic task was like this. It was a sentence comprehension task and the participants were asked to indicate the meaning of a sentence. This was the task. The meaning of the sentence, but the problem was, the manipulation was this: sentences described an event either consistent or inconsistent with the real world knowledge. There were simply some sentences and they had to give the meaning.

So, sentence reading and then consequently they had to give the meaning of the sentence. The problem that was manipulated, the problem that was underlying the task was: some sentences had a scenario which is not consistent with the real world information. For

example, ‘the dog bit the man’. Typically we do not do that. Humans do not bite the; sorry ‘dog bit the man’, but inconsistently ‘man bit the dog’ though that does not happen. So, one is consistent and one is inconsistent.

So, in this particular case this is the target scenario. In case of ‘dog bit the man’ that is normal, that is there is no conflict to resolve, but in the inconsistent situation, there is a conflict. What is the conflict? That there is a there is a meaning to the sentence, that the ‘man bit the dog’.

Simply there is a meaning lexical the meaning of each of the words and thereby the meaning of the sentence, but that meaning does not really match with the real world scenario. This was the linguistic task.

They also had to take part in non linguistic task. One was color-word Stroop task, which we have already seen what it means. So, in this case also it was the similar task; participants were asked to name the ink colour or the color word. The meaning of which was consistent. So, in case of congruent, word red in red ink or inconsistent, in case of inconsistent or incongruent: red in green ink, that we have already discussed in the previous segment, previous part. So, what is a congruent and what is an incongruent condition in a Stroop task.

Similarly, they also had a flanker task, participants were asked to judge the direction of the central arrow, which was flanked on both sides by arrows in the either in the same or in the opposite direction on the way usual simple flanker task. So, what they did was they had these three behavioural task and simultaneously fMRI was also carried out.

So, now we have data from both the fMRI as well as from the behavioural output. Now, our primary interest is to check whether the same general purpose cognitive control networks are activated during both types of task. So, what they find out is observations are, this is medial PFC, left vlPFC and left lateral parietal cortex, all of which are implicated in executive general purpose executive control, were recruited to monitor and resolve competitions in the sentential representation.

So, when they were trying to do the task of sentence representation, sentential representation that is sentence comprehension task in the incongruent condition, or condition that was incongruent with real world knowledge, they find these areas these

brain regions which are well known for general purpose cognitive control mechanism to be activated. So, within this network, even they find even finer representations, they see that dorsal medial PFC as well as vlPFC, within which this particular region has been activated, as well as inferior parietal cortex. So, this was consistently found to be activated for the control process in sentence comprehension as well as in the non-linguistic tasks.

So, this is one rather famous example of both language task, language processing task as well as non linguistic task activating the same general network that is responsible for cognitive control.

Yet another kind of sentence processing that is very commonly utilized is the category of ambiguous sentences. Now, ambiguity can be of various types. In one particular kind, the referential processes are looked at. So, for example, referential or syntactic process themselves sometimes generate two possible interpretations, causing longer reading time and more comprehension errors. For example, this sentence "Ronald told Frank that he had a positive attitude towards life". Now, the problematic part is this, who does this 'he', the pronoun 'he' referred to this could refer to Frank ,this could also refer to Ronald.

So, the pronoun 'he' could refer to either of the two mentioned characters leading to potential confusion. So, this is one kind of ambiguity and in while reading these kind of sentences, what we find that both medial PFC as well as bilateral angular gyrus are activated. Because there is a conflict, there is a conflict which means there has to be a resolution to that conflict.

Similarly, another kind of ambiguity can arise which is considered temporary ambiguity in case where part of the particular target word can have two different kinds of interpretation. For example, executive functions for example, you in a sentence like in a verb like 'assert' might be followed by two possible structures. One is: the direct object assert what? do you assert? 'I assert this' that is one. Another could be that a subordinate clause these are these both of these are possible.

However, more common more readily acceptable is the direct object, that would immediately follow the word 'assert'. So, in a sentence like this, where you have verbs that can be followed by two different kinds of, two or more different kinds of subsequent portions of the sentence, there is a conflict. So, in case of direct object, "the diligent disciple asserted the belief readily".

So, here ‘asserted the belief’ is the object. On the other hand, asserted the belief on the other hand, subordinate clause can also be there ‘asserted the belief would be justified’ right. so till here this is the this is the sentences are the same, but the moment this part appears there is a problem.

So, in a context like ‘the worried friar asserted the belief’ till here there is no problem. The belief is temporarily it becomes temporarily ambiguous at that point when either the direct object or the subordinate clause will be activated. Now, participants usually prefer the direct object equivalent, direct object preference.

So, they prefer usually the direct object interpretation because it is highly frequent, this is how mostly sentences would be formed. However, once you read till ‘would be justified’ you need a re-look at the sentence that no, this is not how it is supposed to be. So, it is against the direct object interpretation.

So, you cannot interpret it in the usual way. So, you need a re-look and then participant obviously, had to return to the subordinate clause interpretation and inhibit the preferred interpretation. So, there are two possible interpretation, till you have read the ‘worried friar asserted the belief’, after that the ambiguity starts and then that because of this competition, control processes need to be activated.

So, what do they find? The control processes are were supported by the same areas that we have been seeing till now, left vlPFC and dorsolateral PFC. So, these are the areas that were found to be activated by this kind of a confusion, this kind of a competition within a sentential context leading to ambiguity. So, these are the some of the references that have reported these findings. This is not only one group, but there are many groups who have find reported similar findings.

Yet another cases, another type of cases, include strongly containing sentence constraining sentence completed by a plausible, but unexpected word. For example, ‘the children went outside to look’. This is, this creates a constraint. Typically, a sentence like this outside till here then you do not expect the word ‘to look’ is not expected as much as ‘to play’ would be expected.

A similar typical sentence would ‘the children went outside to play’ not ‘outside to look’. So, this is where again you need an inhibition of the preferred interpretation thereby there

is a kind of a conflict that needs to be monitored. So, once one the what we have seen in the last three experiments is that three types of experiments is that the there are different kinds of interpretations of a sentence. Sometimes on a one particular interpretation is more common, it is more high frequency word or some or something of in that line. So, then, but the experimental paradigm is such that the non frequent interpretation was activated.

Now, this resulted in a strong inhibition, this had to be inhibited, this automatic interpretation had to be inhibited in order to facilitate the task, given the given task. And in all these cases what we see is that a particular network that are responsible for executive control are activated.

Similarly, we find the same things here as well, posterior positivity or an anterior negativity in ERP, this is not an fMRI study, this was an ERP study.

Thus, what we see here is that sentence processing that was dependent upon conflict resolution and inhibition of irrelevant information, has been consistently found to be involving the general purpose cognitive control network of the brain

Now, we move on to conflict resolution in word production.

Word production has various types. Now, speaking itself includes searching and picking the right word that is appropriate for a particular given , that we already have discussed before. So, sometimes the right words are automatically activated as we have just seen that the children went out to play, it is automatically activated. The word play is automatically already there for you to be used, to be retrieved.

However in certain situations, speakers must voluntarily retrieve the right words from semantic memory and sustain them against competing alternatives. So, in the previous case, we have seen that the children went out to look now to look. Because they are reading the sentence as that, they had to consistently keep it activated and have a constant inhibition of the ‘to play’ candidate.

So, this is what happens in case of word retrieval. So, of in a famous case in a famous paper by Thompson and Schill et al., 1997, they carried out a study, where participants were asked to generate a verb related to a noun, which was associated with many items, without any clearly dominant response. What does it mean? Sometimes, some nouns are

connected to many verbs or a verb is connected to many nouns were automatically connected, automatically generated, they are high frequency associations.

So, for example, ‘hanging a coat’ or ‘singing a song’ and something like this. So, these connections are these associations are automatic. Sometimes there are some associations which are not that automatic which are kind of weakly associated. So, what happens then, this is what they try to find out.

So, if you have a case where nouns and verbs are having an associate that is comparatively weak, then there this leads to high selection demand, because due to higher competition. Because there are too many words that are connected and, but all of them are weak connections.

So, now you have to go search for one that is apt or if it is given to you already, for your attentional mechanism to be sustained on that you need to continuously suppress the more strong connections. So, what they found in this case was again the left middle vfc was activated. Not only that, it was also found that patients who had a focal lesion in this particular region, could not make a response when the cue noun had many associates.

So, this shows that not only in normal participants, normal subjects they had a control process in place when weak associations were processed. They also found that in patients who had a lesion in those areas, that was found to be activated if you have a lesion in those places the patients could not form the associations at all. They could not make a response to with when the cue noun had many associates.

So, not only in retrieval, but also in access in lexical items, the control process in accessing lexical items have also been found to utilize similar kind of network. For example, in a task in a yet another famous study, in this was an association task again. So, participants were asked to select target which was associated with the cue.

Now in one case for example, ‘candle’ is more strongly associated with ‘flame’ rather than with ‘bald’, similarly candle is weakly associated with halo over ‘exist’. So, this is the background within which they carried out the study.

Now, if the association between the cue and the target is weak again automatic retrieval processes are insufficient. So, it cannot be, if the target cue and target pair are weakly

associated, automatic retrieval will not work. In that case there has to be a voluntary search operation for the participant to go back in semantic memory and retrieve.

So, that control that there is a control mechanism at that level as well and this, as expected, activation was found in the left anterior vlPFC. So, what we see is that very often most consistently vlPFC has been found to be activated in many such studies, many such experiments, whether it is sentential or at word level processing, word level processing when there is a conflict.

Semantic processing as well have found the same kind of same kind of activation level. So, again what we see is the VLPFC is critical for performance of tasks that demand access to an evaluation of semantic knowledge. In fact, this is connected to the study we just mentioned. This particular group as Badre et al., has have done a number of series of studies on this in this particular domain. And in all cases what we see is that the consistent finding is that ventrolateral PFC is almost always found to be activated.

So, ventrolateral PFC is critical for various kinds of tasks demanding semantic knowledge, retrieval, word retrieval and access to word retrieval in the semantic memory and so on. So, left VLPFC control mechanisms are critical when a subset of knowledge that is task relevant, must be selected over a competing task subset of irrelevant knowledge.

Irrelevant and it is it becomes more competitive when the irrelevant subset of knowledge is more, is higher frequency word or more commonly associated and so on. So, that is the that is the scenario when inhibition has to be stronger. So, control mechanism has to be stronger and that is when we find this kind of activation of various general purpose cognitive control network.

Now, even though we have enough already a lot of evidence coming from various types of language processing, be it sentential level or a word level or at the level of meaning and so on, the largest amount of data, largest amount of work has been actually coming from bilingualism.

A lot of interesting work has happened. So, as a result of which, large amount of literature actually exist in connecting language and executive control in this domain. The reason is that both the linguistic systems of a bilingual are active when even when only one is in use. This automatically creates a state of competition that needs to be dissolved.

A bilingual is already bilingual mind is already all the time in a state of competition because the two languages of a bilingual, or many languages of a multilingual, are all the time active even though there is no demand on the other languages. Even when only one language is being utilized, other languages are simultaneously active.

Now, this is already well known knowledge, it is already has been has all been established for a over a long period of time now. So, what we know in this domain already is that both orthographic and phonological properties of the words of the two languages are active and they influence performance, even when the bilingual is highly proficient.

One would expect that a bilingual, who is not very high proficient in the second language, would be dominated by or would be would have more interference from his first language on the second language. But that is not the case. The findings suggest that even in case of very high proficient bilinguals, the properties, the orthographic, the semantic, the phonological properties of both languages impact each other in case of any kind of bilingual language processing, even when only one language is utilized.

And so, work initial work focused on cognates and inter lingual homographs to prove this, but now a large range of data also point the same situation. So, what is a cognate? Cognate is are those words that have form and meaning converging. So, in case of for example, in the in case of Dutch and English pair the word ‘hotel’ is a cognate. Because in both English and Dutch they look the same, they are pronounce the same way and they mean the same thing.

So, the form and meaning are same, but in some words they are even though they look similar, but they are not the same. So, the word ‘room’ in English is of course, we all know it is a room what room means, but in case of Dutch the same word means cream. So, this is an inter-lingual homograph. So, they are written similarly, but they do not mean the same thing.

So, experimental paradigms that have used this kind of words that have, that give us a large amount of data as to how this interference really works. So, both spoken and visual word recognition prove that bilinguals do not function like two monolinguals. Meaning that bilinguals’ both languages interact with one another and as a result this is not a bilingual is not two monolinguals put together.

So, when the when a bilingual speaks in language 1, only language 1 is active, when he speaks in language 2, only when language 2 is active, it does not work that way, all the languages are active all the time. And this effect of interference from both languages on each other are seen. So, it is also this effect is also found in case of languages that have different script. One may argue that languages having same script like Dutch and English have some similarities, so that there is interference.

But it also found in case of different script languages like Japanese English and even in bimodal bilinguals. Bimodal bilinguals are those bilinguals that use two different languages two different types of language using different modalities. So, one is the verbal language another is the sign language.

So, in case of bilingual who speak one language and sign another even in that scenario we find interference of one language on to another. This is also seen to the extent this effect is so strong that this is also seen when speakers hear unrelated L 1 as background noise while speaking in their L 2.

So, many of these many of many researchers many groups have looked at these issues all of these issues and in their finer nuances and thereby using tasks that require bilinguals to suppress the irrelevant language. So, there is a there is a task in Dutch going on in the English is not to be utilized, but the experiment still finds impact of English language on the Dutch language performance and so on.

So, in all those cases in all these different kinds of studies, what we find is that the suppressing the in irrelevant language and sustained activation of the target language are also are controlled by or at least supported by the left dlPFC as well as the supplementary motor area.

So, basically in case of a bilingual whether it is word processing tendency processing or whatever different kinds of processing that requires suppressing the irrelevant language, irrelevant for the task at hand, that language we see the same kind of activation that we have seen till now, most notably the left dlPFC.

Similar kind of control mechanism are found in language switching as well. Language switching experiments are very fascinating in terms of bilingual language processing

language switching tasks require participants to switch between languages, so on the basis of a cue.

So, they have they are participating in, let us say, a picture naming task. So, there is a picture on the screen a line drawing basically and they have to name the picture. So, for some time they will name the picture in language 1 and then there is a cue on the screen and they have to shift to language 2 and now use language 2. There are many such many manipulations of this basic design.

It can be a picture naming task, it can be a comprehension task. Basically switching the task would require you to utilize one language at a time. And then after that there is a cue they then you have to switch. So, there are many manipulations, many permutations and combinations of such tasks.

Sometimes there will be after each after two three tasks there will be a change. Sometimes there are single language groups and in between there is a mixed language group followed by another single language group and so on. So, language switching tasks have various paradigms, but primarily the task is to switch between two languages on the basis of a cue. Sometimes the switching can also happen within language, in that case the task is switched not the language.

So, if it is within language switch the task is different. So, in case in one case identifying noun, in another case identifying verb, but both within the English language, let us say. Similarly, but in case of within language between language switching, you are naming the word in one language and then naming the same thing in a different language; these tasks are aimed at finding the switching cost.

Now, switching cost is a very very important concept in bilingual research. And basically it shows how much time is taken how much time is let us say how much cost in terms of time you pay when you switch. So, switching from L 1 to L 2 versus switching from L 2 to L 1, what is the time lapse which is compared to the single language block.

So, if you have a one block where you have to name only in English, how much time you take for how, what is the average reaction time as opposed to when you switch. So, switching cost is an indicator of many things in bilingual bilingualism literature. Typically, switching cost reduces when the proficiency of the bilingual in L2 goes up.

But in any case, switching cost basically is what we find try to find out and how it is modulated across variables. There can be many variables. Proficiency is one, but there can be many other variables. Now, this particular task will show this particular switching cost shows the language control ability of bilinguals in various scenarios, in various conditions, various experimental conditions that manipulate different kinds of variables.

In few studies on Spanish-English bilinguals there was a particular study on picture naming, this study was like this. Participants had to name pictures according to a cue. So, the cue was live. So, that between language condition refers to changing between Spanish and English, interchanging between Spanish and English and there was a cue.

So, participants were asked to name pictures of objects in English, if it was cued with the word ‘say’. So, basically there will be a there will be a cue either written or auditorily the word ‘say’ comes and then they will say the name of the object, they will name the object. And if it is or if it is in Spanish [diga] then they will say it in Spanish. So, this was the cue that is how the switching happened.

So, in some cases the word ‘say’ will appear and then they have to name the picture in English and when it is the Spanish version they will have to speak in Spanish. So, there was a switch on this ground.

This experiment also had within language condition. In case of within language condition, participants were asked to name a picture if in English as the action depicted. In one case they were supposed to name the action that is the word if the or if it was cued with the word ‘to’. So, if there is a cue said ‘to’ now you have to mention the verb what is happening in the picture.

So, in this particular case the boy is eating a hotdog. So, what is happening? What is the verb here? How do you know you have to say the verb? By the cue by using the cue ‘to’. So, when the word ‘to’ comes participant had to say ‘eat’. However, on the other hand if the cue word was ‘the’ then they have to name the object what was being eaten. So, in this case, ‘the hotdog’. This was the this was how the experiment was conducted.

So, they were both within language and between language switching on either on task or on language.

What they find is that for both the between language and the within language conditions, the switching processes were sub served by again left dlPFC, left vlPFC and we already know anterior cingulate cortex which is ACC and the left caudate. These are the regions that were found to be activated during the process of resolving the conflict in both cases, resolving during the switching process.

So, both whether it is a within language switching or it is a between language switching. Within language remember it is not a language switch, it is just a task switch, but in within between language cases it is a language switch, but in both cases they find the similar brain areas were activated. Those areas that are considered to be the general purpose cognitive control network. Now, this various groups have reported similar kind of findings on these in this paradigm.

Now, let us move on to the bilingual advantage question.

The bilingual advantage question or the debate has been a very a hot topic within bilingualism research. This basically talks about a particular kind of advantage that the bilinguals may have over monolinguals. Now, the findings from bilingual as well as monolingual language processing point to the fact that co-activation happens between language processing and general purpose cognitive control neural networks.

So, this led to the belief that bilingualism that led to the belief that bilingualism give rise to better cognitive control. So, in case of a monolingual also, there is you find whenever there is a conflicting scenario, the general purpose cognitive control network gets activated.

In case of bilinguals, that kind of a competition is all the time present just by virtue of being a bilingual, we are supposed to be juggling between two different systems. Two different systems as in, in terms of phonology, morphology, syntax you name it all kinds of. So, there is always a process of control in place, as for the researcher. So, being a bilingual automatically means suppressing the task irrelevant language.

So, right now I am speaking in English, but all the other languages that I speak, are also simultaneously activated or they are active to be utilized. But I have to, so my brain has to suppress those languages constantly and keep my target language activated as long as this is relevant.

So, this particular idea has given rise to the notion, given rise to the hypothesis that because the bilingual is constantly employing the control mechanism just by being a bilingual, just by even when they are speaking in only one language this might, this probably could have a spill-over effect on the general purpose cognitive control mechanism itself.

For example, there are many various kinds of cognitive tasks various kinds of challenging demanding cognitive tasks that have been found to be having a spill-over effect on other types of executive mechanism. For example, when you lot of research has gone into meditation. So, by meditating you can train your brain. Similarly, by training hard to, even body builders by training hard they are basically training their selective attention mechanism this might have a spill-over effect on other domains.

Similarly, people who play video game for long period of time will have trained their selective attention and sustained attention for a very long time, which has been already found to be having positive effect on many other skills. So similarly, bilinguals because they are constantly they are constantly employing that cognitive control mechanism, this might this could actually lead to having a higher cognitive control capacity in the bilingual. This is famously called the bilingual advantage.

So, research in this domain has been very very fascinating and also rather controversial.

Now, let us start with the developmental point of view. A lot of research has focused on how being a bilingual makes us smarter, makes people smarter or whether does it make it make people smarter. So, a large chunk of research actually focused on children. So, bilingual children versus monolingual children and how they function in various kinds of tasks that require response inhibition?

So, basically how well established the cognitive control mechanism is or how whether one has a higher or superior cognitive control mechanism. So, but to because for a bilingual we have to constantly see, to choose which system to use and which to stop from interfering and we have to also learn to ignore irrelevant information. This has the consequence of creating more general expertise in resolving conflict.

Now, Ellen Bialystok's research of many decades have shown that bilingual children outperform their monolingual counterpart in simple tasks that require cognitive control, that require in irrelevant information to be ignored. She has used, she and her group has

used, various kinds of tasks Wisconsin card sorting task and various simpler tasks for children to show, to find out whether bilingual children have a higher response inhibition system in place. And more or a more less more often than not the findings point to that possibility that bilingual children, children who are learning 2 languages or who speak 2 languages, more commonly have outperformed their monolingual peers in tasks that require inhibition, in tasks that require irrelevant information to be ignored.

Yet another domain which is again very controversial, but some findings point to the fact that a bilingual people, a bilingual person probably has an advantage over monolingual peers in terms of the onset of the various kinds of diseases like Alzheimer's and so on. So, there has been. So, this has led to the belief that the bilingual people have, in the elderly population bilingual people have an kind of a protection against cognitive and attentional deficit, decline that typically affects people in the age after 60 years.

So, Alzheimer's and Parkinson's and so on, the large number of data has been collected in this domain to show. In fact, a large a number of data actually point up to the fact that they have later onset of the diseases which has been of course, challenged and there are lot of work going on in that domain till now. So, these findings prove that bilinguals are able to manage their attention to a complex set of rapidly changing task demands which is better than their monolingual peers.

So, Bialystock's one particular study we will mention here of Bialystock; this was in 2004. So, she had taken both old and middle aged monolingual and bilingual subjects on several variations of Simon task. Remember Simon task, that is there are that is the that is the special correspondence task between source and target. So, the task in this case was to press right shift key with right index finger on seeing a brown box and left shift key with left index finger on seeing a blue box.

So, we have already seen this task, how it goes. The findings shows that response was faster and more accurate when there is a special correspondence, as a as expected, between source and target. And when there is a there is the correspondence is not there when it is an incongruent condition of course, response was slower. But more important finding is that the bilinguals outperform monolinguals in these studies.

Now, this kind of findings and many other similar kinds of findings have now taken have been now taken to a step further. And one of them one of the very important in very and

an influential hypothesis in this domain is the ‘adaptive control hypothesis’ of Green and Abutalebi in a famous paper in 2013. They have talked about that bilingualism has the way the kind of bilingualism that we practice, may have different kinds of reaction, they may have different kinds of effect on the different kinds of cognitive control processes.

So, what they basically talk about is the interactional context of bilinguals. Interactional context they define it in three different ways. So, there is a three way difference between in terms of switching language. So, language switching, we have just seen that language switching and task switching are similar in terms of response inhibition and so on.

So, depending on that they have a three way difference single language, dual language and dense code switching context. And they say that depending on what context on the bilingual actually comes from will have difference different kinds of effect on these various types of cognitive control process; goal maintenance, conflict monitoring, interference, separation salient cue detection.

So, basically they further segment the cognitive control processes in these sub processes and they say that each of them might get differently affected by the kinds of interactional context that the bilingual comes from. So, adaptive changes also will happen in the neural regions and circuits associated with specific control processes.

So, this is a very powerful hypothesis and there is a lot of support for adaptive control hypothesis from literature as well. So, I have just quoted a few. So, interleaved picture word comprehension and Flanker task in Chinese-English bilinguals find this find the support.

Similarly, language switching task with English-Mandarin bilinguals. Similarly it was also reported that bilinguals with balanced usage of both languages showed lower switch cost. This has been also found out in by Albert Costa in case of language switching. So, if your proficiency goes higher, your switching cost goes down. So, they find that lower switch cost in case of balanced usage of both the languages in trial making tasks than bilinguals who spoke only one language at home.

So, people basically it is the usage of language of a bilingual that also. So, you see it is not only just being a bilingual that affects your cognitive control mechanism, but also the kind of bilingual you are, in terms of using those languages. Whether it is a single language

context, dual language or a dense code switching and they find different fascinating results with that.

So, there is a lot of support. A similar kind of result was also reported from Stroop and delay gratification task in yet another group's result. Of course, there are also findings that do not support the adaptive control hypothesis and as a result there is a relook at the finer aspects of this hypothesis.

More recently, bilingual's cultural context has also been investigated with this within this paradigm. So, bilinguals what kind of cultural context and whether it gets, whether it does affect, whether a bilingual's being a high proficient bilingual or whether it is in the person is a bicultural bilingual or just a bilingual without the cultural aspect attest and so on.

So, basically various subtle very subtle nuances within bilingualism is now being looked at to understand cognitive control mechanism that is connected, that is considered to be connected with bilingual bilingualism. So, the level of control in the presence of incongruent culture cue has been found to be different in different kinds of bilinguals.

So, the famous studies there are some famous examples from these Chinese-English bilinguals in language production study where incongruent phases created a delay in the response in the L 2 in the English language. So, pointing this particularly points to the cultural angle to language cognitive control relationship.

So, it is not just the fact of bilingual not all bilinguals show the same kind of control mechanism to be in place. So, what is happening more, what is it only the abstract kind of just speaking two languages or it is certain other factors that are part of know being part of a community, speech community part of speaking a language and so on that is now getting investigated.

In one such study in by Roychoudhury et al., in 2016 showed the impact of culture cue on naming. So, this was this study was carried out on Bengali-English bilinguals. So, the cultural cue here is the Howrah Bridge and then they had to name, this was a picture naming task. So, they see the picture of the Howrah Bridge. So, automatically the moment you see Howrah Bridge your cultural aspect that is activated is the Bengali culture.

So, then there is a there is a gap and then there is the picture emerges and then the task was to name the picture. And so, in whether when this was this is an incongruent condition. You see a Bengali picture and you have to name the picture in English then there was an incongruency effect in congruency effect in the sense of inhibition. So, response was slower in when there was an incongruent picture.

Basically, this refers to the fact that the cultural background of a particular language does have an impact on the other language's cognitive control capacity. So, how much you are able to inhibit those responses? So, in this case that inhibition was not found, it was found that the cultural cue was actually affecting. So, it was not only active, it was interfering with the second language output

However, in another study in a similar study on a Rongmei-Meitei bilinguals in Manipur we found we did not find the inhibition at all. So, this study was carried this is recent study and in this case also this was the comprehension task, translation equivalent comprehension.

So, these two words mean the same thing. The task was to say whether the second word is a translation of the first word or not; manipulation was this picture. So, in between two pictures there was a culturally sensitive image, cartoonized image of a person wearing the culturally specific dress.

So, in this case and, so, when the task was to see if it irrelevant incongruent condition results in higher reaction time or more errors. So, in this case however, the results do not show any kind of inhibition, whether it is a congruent picture with this language or not, the results do not show any kind of inhibition.

So, basically this shows that this is the particular kind of bilingual community, who do not get. So, basically there is a higher response inhibition that is present in this particular community that was studied.

So, basically this refers to this takes us to the possibility that the kind of bilinguals that are studied will have to be looked at a very finer level. But overall, we can sum up the results by saying that the studies mentioned show a relationship between general purpose cognitive mechanisms of the brain and language processing. This is a kind of this is the

general outcome of the all the research that have been just now talked about, basically the relationship between language processing.

So, language processing in different kinds of conflict conflicting situation, competitive situation be it at the word level or whatever, there is a relationship with the general purpose cognitive control mechanism, this is the finding. However this claim has become rather controversial recently and there is a different view to this entire story.

This view has been proposed by Evelina Fedorenko and her group and there are also some other groups who are now working on the finer nuances into this. Now, there are new evidence that are emerging from the studies of these various groups of studies, groups of neuroscientists that the overlapping of general purpose neural network for control and language function is too simplistic.

What has happened in the past as per Fedorenko and others is that, the finding that have been reported is too simplistic because they are reporting always a large area. In terms of the brain, in terms of cortical region we have to be sure about you know locating a certain functional domain in a very very small, tiny area. The just saying vlPFC is active is very simplistic. So, this is the this is the standpoint that they are taking.

So, vlPFC fine, but what area within vlPFC is what they are talking about. So, general you can just mapping them together is not enough. And they have proposed this is the result of many years of research by these groups and now they propose that there are actually two networks in the brain. There is one general area and one language related area. So, they name them like this ‘language related area’ and a ‘multiple demand network’.

So, there are two networks that are there in the brain that are responsible for different kinds of control mechanisms. So, and these areas lie side by side. So, basically finer methodological interventions is what they propose, that are needed in order to find out the subtle differences between these two areas.

So, what is language area? Language area is basically, they propose is only in the left hemisphere and it shows robust activation in language comprehension and production. So, all kinds of language processing that needs control mechanisms, that is there in the left hemisphere.

So, these are the what are the areas? Frontal, temporal and parietal regions of the left hemisphere. So, they have mapped out a particular network within these three areas that are in the left hemisphere and that show a very strong activation for language related processing. This is particularly selective for language processing over non-linguistic task.

So, what does this area do? This supports word meaning and combinatorial processing. So, various studies that needed a resolving, meaning related or semantic related competitions, similarly various kinds of combinatorial processing as well. Combinatorial as in terms of both syntactic and semantic processing of within language processing that is what they found was to be this was this area to be responsible for.

Studies show that this region is not activated while performing non linguistic executive functions. Remember if we go back a few slides we have seen that various studies have pointed out that participants when they participate in resolving conflict in a linguistic scenario versus when they are resolving a conflict in a non-linguistic scenario the similar kind of brain regions or sometimes overlapping brain regions have been found to be activated.

However, research by these various groups they show that this language related area, language area let us call it, that language area is not activated when non-linguistic tasks are, non=linguistic executive function related tasks are carried out. So, in case of let us say Flanker or Simon task or any such Stroop task, whatever they are carrying out the this language area do not show activation.

What they show? These areas show only strong activation for language processing. So, they have used finer mechanisms in order to find out the differences

On the other hand, what they call multiple demand network, which is called MD network in short; multiple demand network is present in the brain bilaterally. What does this mean? Whereas, on the one hand the language related area is only there in the left hemisphere the MD network, which is the multiple demand network, is present bilaterally that is in both sides of the brain, both the hemispheres and this is there in the frontal and parietal cortex.

Of course there are the smaller areas that they have mentioned, but I am just giving you a brief overview. Now, this area, what they find out is this area is responsible for different

kinds of demanding tasks be it arithmetic, deductive reasoning, problem solving so on and so forth, but not language.

So, various kinds of demanding tasks that requires a control mechanism to be in place they find the this particular area to be active. And this is also sensitive to the difficulty level of the task. So, depending on how difficult a maths problem is that will be again that will again show a different kind of activation level. Similarly, deductive reasoning, problem solving and so on. So, this particular area is found to support goal directed behaviour, cognitive control, attention so on and so forth.

We, this is what? These are the group these are the things that are grouped together as fluid intelligence we have already talked about. So, executive control mechanism, executive function or cognitive control or whatever you call it they are basically the hallmark of an of intelligence.

So, you have a goal directed behavior here, cognitive control all these are supported by the multiple demand network. So, it can the you can have various kinds of demands on this network that can that are non-linguistic in nature. So, it can be anything that requires this kind of control.

So, as a result of which goal directed behaviour, cognitive control in short a fluid intelligence is controlled by this particular area.

So, the finding of these groups is that language and the MD networks are functionally distinct. So, whereas, language area is responsible for conflict resolution in case of language processing, on the other hand MD area is responsible for conflict processing, gold directed behavior and so on and so forth, but not language processing. And they also find out that MD network do not support core aspects of language interpretation.

However, this has to be taken with a pinch of salt, because Fedorenko herself has pointed out in one of her latest papers that there is some there seems to be slight activation of this network in certain kinds of language processing, certain kinds and they are still working on this. But largely, on overall, the MD network do not support the core aspects at least of language interpretation.

Now, what do they call the key signature of linguistic processing? This is very important, what is considered a key signature of linguistic processing and what is a peripheral processing. So, stronger response to meaningful and structured linguistic representation, this is what they take to be the key signature of linguistic processing. These are the core linguistic processing, language processing related areas and this in terms of these in representations MD network do not have a role to play, but language area does have.

More evidence come from different other researchers as well. So, in case by using signal fluctuations between the brain regions in using both within and between systems they also show no overlap between the two networks. Also some researchers have pointed out that the time course of development of language and executive control mechanism in children, from childhood to adulthood also differ.

So, when a 3 year old child can have the language system in place perfectly fine in a normally developing child, the executive control mechanism gets properly kind of settled by adolescence or young adulthood. So, even in terms of the developmental aspects of these two functions are different. So, how can they be how can there be an overlap, because language function is developed far more quickly than executive control functions and so on and so forth.

So, there are evidence coming up from various domains of research and it is still a very a richly debated claim. So, one question that arises is that, why did not the previous researchers find this out? Why do we have such a large number of research output pointing to the fact that general purpose cognitive mechanism is also responsible for language processing?

The reasons that Fedorenko gives is that the it is primarily a methodological issue. Methodological issue because the typically the problem arises because there is an averaging of brain areas in common space. So, basically we talk about the you know the DLPFC or the mPFC and so on and so forth.

This is the large area. And basically we average the there is an averaging of various individuals and then finding out, but then there are, that cannot be done because across individuals precise location for language area may vary. So, this is what actually they are working on. They are looking at individual level rather than at an averaging kind of a study.

So, averaging brain in a common space and then voxel based performance, these are the find these are the problems that she refers to why we have the kind of result we have had. So basically, the methodology has to be changed there has to be more fine tune methods to be utilized and also taking yet another very important aspect into the consideration which is the inter-subject differences.

So, each subject, each human has slightly different regions for language functions. So, that has not been taken into account by most of these studies and that is why it is kind of simplistic in her terms. And also because these regions lie side by side, they are very close to each other. And so, there is always a possibility of finding of you know confusing one with the other.

So, there are control mechanisms in the brain that are sensitive to language processing of course, there are. But these are different and distinct from the general purpose cognitive control network. So, this is how it looks like at this point of time; this also points to a possibility that linguistic mechanisms are more closely linked to social mechanisms.

This is a claim that Fedorenko and her group has made that the reason why we have a different distinct network and the way it behaves, the way it the control mechanism really spells out is probably because language is more connected to social mechanisms. And thus that is why we find we have to give a more focus on meaning and communication.

In fact, that is what her most of her tasks also do, that the that what they have developed. So, meaning and communication are the core of language mechanisms and that is why it is also connected to the social mechanism. So, this field is growing every day and of course, newer evidence is emerging.

Till few years back the received wisdom was that language functions, language processing and general purpose cognitive control mechanism are the same; they use the same control network neural network. But now there is a challenge to this and there is lot of data coming out from these different groups. And we are still learning, what is what the story is still unfolding gradually.

So, this is where we will end the part 2 of this. There are lots of references, I will add at least a couple of reference for each type of studies. And that will give you a good enough

idea about how the research, what are the directions that the research has taken place and what are the primary findings. In the next segment we will take up simulation.

Thank you.