Bilingualism: A cognitive and psycholinguistic perspective

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Module - 07
Part - 02
Lecture - 17
Executive control: Bilingual advantage

Hello and welcome back. We are in module 7 and today we will start with part 2 of module 7. So, in this module we are looking at the consequences of Bilingualism. What are the effects of speaking more than one language? So, in the first part we have looked at the linguistic effects.

There are effects in terms of language skills at various levels in metalinguistic awareness and which is seen through various kinds of experimental paradigms where language related tasks are given to participants and how monolinguals differ from bilinguals is what we have looked at.

So, we have also seen how different levels of those linguistic tasks that have certain different amounts of dependence on executive control can yield different results for bilinguals versus monolinguals versus bilinguals. Now, we will move on to the Executive Control mechanisms.

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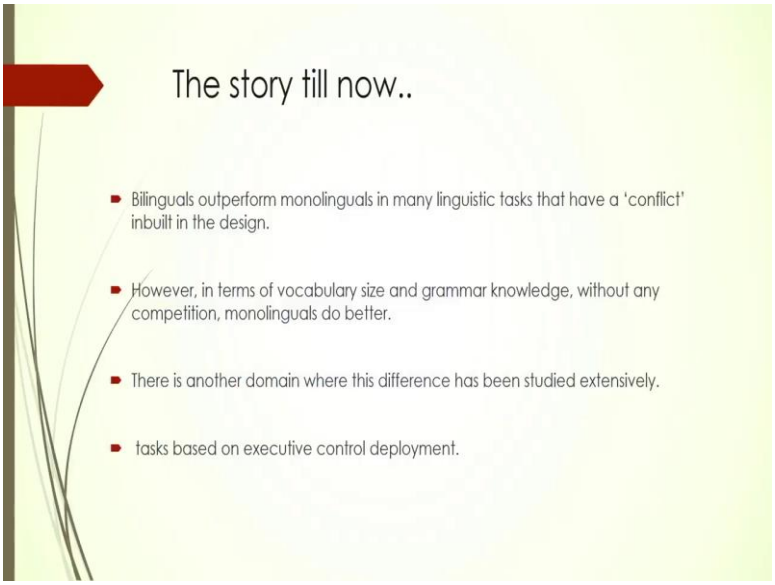

So, bilinguals have, do bilinguals have different mechanism with respect to executive control. So, the story till now this is a quick recap. Bilinguals have been found to be outperforming monolinguals in many linguistic tasks as well. The specially particularly in those tasks that have an amount of conflict built into it any kind of conflict.

So, there can be a conflict between grammaticality and semantic aspect and so on. So, if there is any kind of conflict inbuilt then the bilingual advantage will be visible. Bilingual advantage meaning bilinguals doing better on the same task as opposed to monolinguals.

However, we have also seen that in terms of vocabulary size and grammar knowledge which is completely linguistic aspect of the experiments that is where we found that the monolinguals were doing better than the bilinguals. Now, there is this other domain where we will start today. The other domain that has also been extensively studied in the last few decades, which is the domain of executive control.

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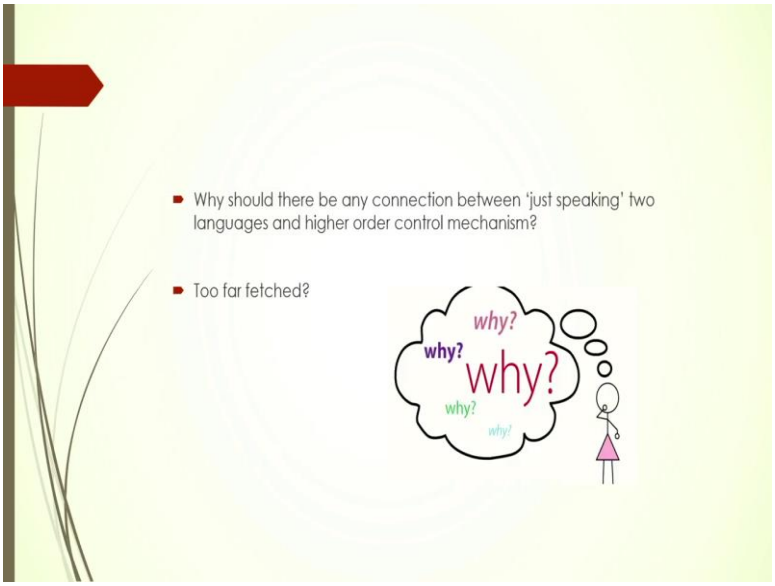

Now, one might think that bilinguals speaking more than one language or a multilingual for that matter, naturally we will be expected to have some repercussions, have some effects, some consequences of speaking more than one language. That is fine as far as you are talking about languages, that is fine.

How and why should we be thinking of connecting language related abilities with executive function mechanism? So, what is it? What is there all about, how is this

connection even proposed? So, just speaking two languages and having a better a higher control mechanism, how does it really work out?

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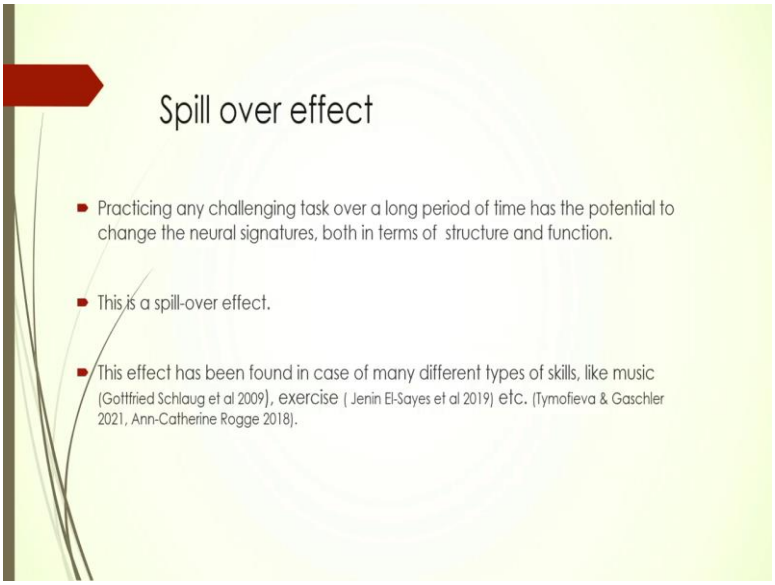

It works out because of a phenomena called neuroplasticity. Neuroplasticity or in a more common layman term we can call it a spillover effect. What is spillover effect? Spillover effect basically talks about that if primarily our brain is plastic, plastic as in it can be modified, modulated through different kinds of training.

So, if you have, if you depending on different kinds of task demands the brain tends to adapt to those kinds of challenges and as a result of which it changes itself. So, practicing any kind of challenging task over a long period of time has an impact on the brain structure itself.

The structure and the functional aspect of brain are open to changes, brain is not static. So, basically what it means is that it is the brain that we are born with after the first few years of childhood when the brain goes through structural changes and modifications and maturity.

After that the brain should, you know when it is ready it should remain that way all our life, but that does not work that way. That is not how it is. Brain changes over our entire life span depending on the kind of tasks that the brain has been given to do. So, this is what is called the spillover effect. In research, it has in neuroscience related research it

has already been seen that different kinds of complex cognitive tasks have a strong impact on the brain.

So, research is already, we already have adequate data in terms of you know music and exercise and various other kinds which has been found to have a spillover effect. Meaning that over a over prolonged period of time, if you practice any of these things brain has been found to have different structural properties as well as different functional properties as opposed to people who have not been using this kind of tasks basically the control population.

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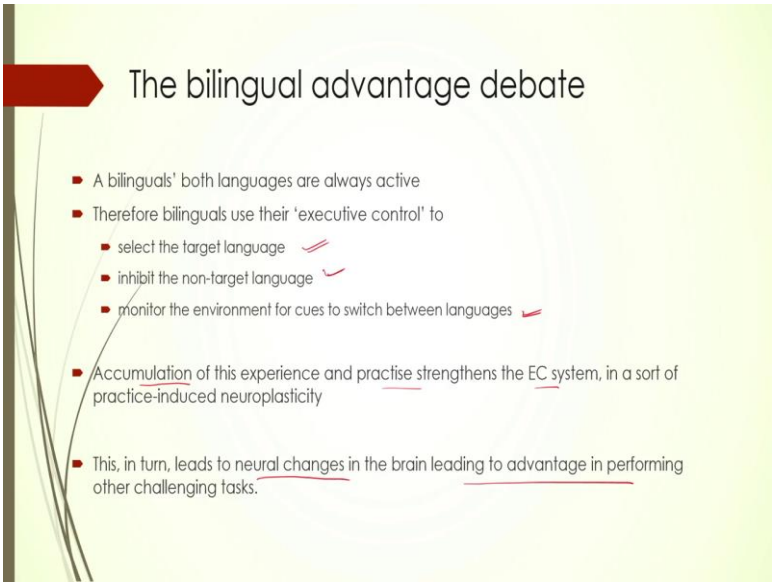

So, there a there is already an existing large amount of data that shows that spillover effect does exist and that spillover effect is basically based on various kinds of challenging tasks. Now, bringing these two languages to bilingualism is very easy, very easy because bilingual's both languages are always active, we have which we have already seen in the processing literature. That bilingual's both languages are active at every level.

So, morphological, phenological, syntactic, semantic at all levels they are active simultaneously. And hence you need an amount of control mechanism in order to do these things. We have already talked about this before. So, what does that control mechanism do for bilinguals? That it helps select the target language; it helps inhibit the

non-target language as well as monitor the environment for any cue for on the basis of which you may have to switch languages.

So, code mixing and code switching are very common properties in bilingual societies. So, we are always alert, we are always looking for cues in the environment based on which we may need to change. So, while we are keeping one language active and suppressing another, we are also keeping the possibility of shifting open. So, that needs a very fine-tuned control mechanism and that is exactly where we are we expect a change in terms of bilingualism.

So, accumulation of this experience, it is very important that the number of years that you have spoken two languages that that is one important variable. So, accumulation of this experience and practice strengthens the executive control system, EC stands for Executive Control system in a sort of practice induced neuroplasticity; neuroplasticity in terms of practicing various task which are challenging that has already been found.

Now, if you practice if a bilingual by simply by virtue of being a bilingual, being able to speak two languages flawlessly means that they he or she is constantly doing all these activities even though they are not aware of it.

Now, this kind of a constant practice will strengthen the executive control system which in turn will lead to neural changes in the brain leading to advantage in performing other challenging tasks. So, basically, we are trying to see if bilingualism is at par with other variables like music or exercise or many other such finds such cognitively tasking work that the brain does and if the effects are similar.

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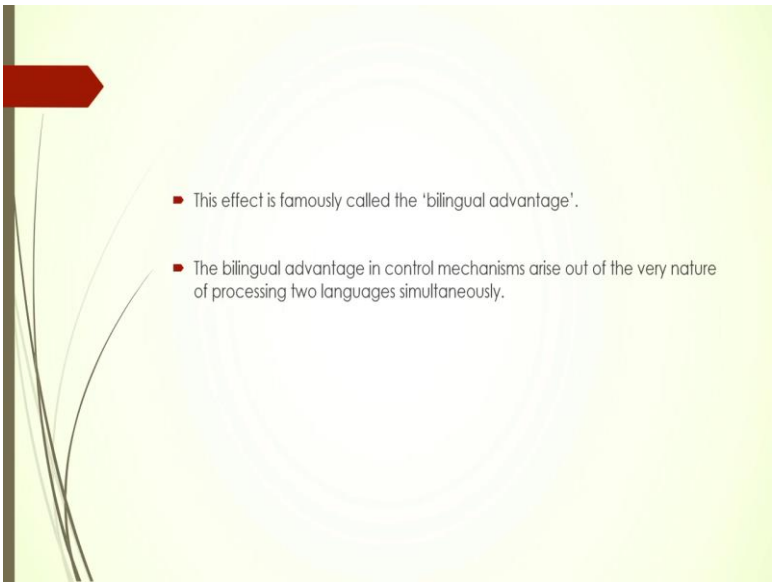

So, this is the effect, this particular effect of the effect of bilingualism on cognitive control or executive control mechanism is called bilingual advantage. It has a name; this is called the bilingual advantage. So, what is bilingual advantage? Bilingual advantage is the role bilingualism plays in fine tuning or sharpening or enhancing our executive control mechanism leading to neuroplasticity in terms of different structure and function of the brain, various brain regions. This is basically what we will be looking at.

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Now, general findings, this area has been researched for quite a few decades now. And the general finding, overall finding points to a the existence of bilingual advantage. So, one of the pioneers in this area of research is that of Ellen Bialystok, Bialystok's research for she has been working on this for more than 20 years now. And her entire range of work primarily has shown that bilingual children perform much better than monolingual children on tasks that require the irrelevant information to be ignored, right.

So, if there are various kinds of task, various kinds of cues in the environment, but only one is relevant for your current goal, how well you suppress the cue that is irrelevant, goal irrelevant at that given point of time is a matter of executive control. And her research has found that typically in all cases bilingual children her work on children has shown that bilingual children outperform monolinguals in all of these cases.

Similarly, bilingual elderly persons also seem to have a particular amount of advantage over elderly monolinguals. A certain amount of protection against the cognitive and attentional function decline. We all know that with age we have a possibilities of Alzheimer's and Parkinson's and various other diseases and in general there is a decline in cognitive functioning.

So, in that domain also bilingualism seem to have some amount of protection that it gives to people in the elderly population. So, these findings prove that bilinguals are able to manage their attention to a complex set of rapidly changing task demands. Now, this is exactly what we will now see in a little more detail.

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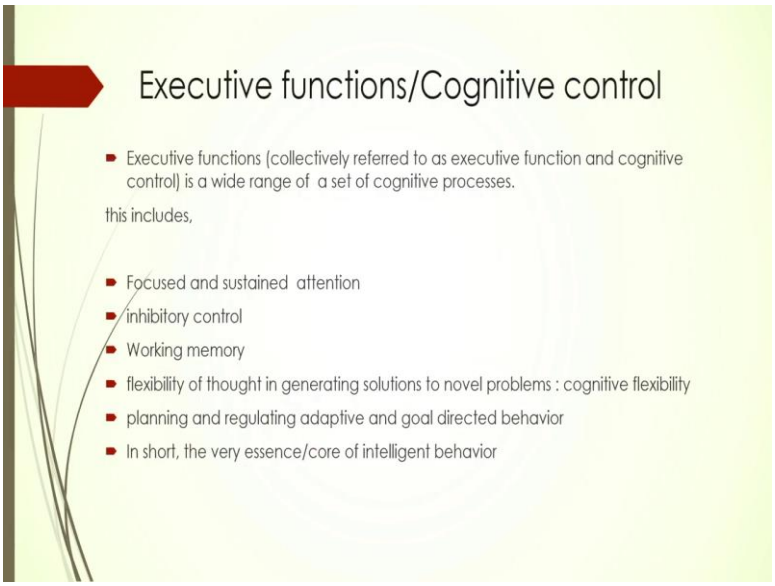

So, what is before we go into the experimental findings linking bilingualism to higher executive control, let us see what executive control basically is all about. This is we will not get into the details, but just a few pointers what it is. So, executive functions are also called executive function or cognitive control. We will be using them interchangeably here because for this course it does not really matter even if we do.

So, these are the things that are part of what we call cognitive control. So, there has to be there is attention, there is a sensory motor reaction, there is memory, the involvement of all of these together and a very fine balanced coordination among all of these is what builds up or what creates what we call executive control mechanism.

Basically, what this is a part of our top down processes as to what to do in a particular given scenario and how to do it best. So, in order to do that we need to be attentive to the current goal, we need to have an inhibitory control to suppress all those outputs, behavioral outputs that are irrelevant for that given point of time, working memory has a lot of important role to play.

Then you also need flexibility of thought there is a common saying that adapt or perish. So, this basically takes us to the flexibility, cognitive flexibility or today it is called fluid intelligence. So, cognitive flexibility is nothing but changing new strategies, mental strategies, cognitive strategies with respect to the changing task demands.

So, if the cue changes automatically you need to update your brain needs to update and react accordingly that is called flexibility. So, generating sometimes generating new solution for new problem all of that. So, this is basically what it is. So, it is the core of intelligent behavior, core of essense of intelligent behavior. This is what cognitive control is.

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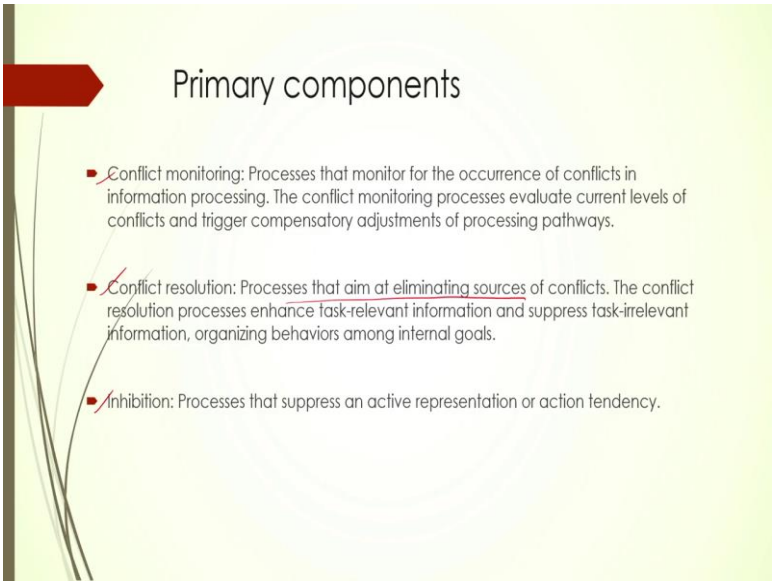

For our purposes we will focus only on these few things. Primarily if we break down cognitive control there are three main components conflict monitoring, conflict resolution and inhibition. Conflict monitoring as in one has to be there has to be a monitoring system in order for us to identify potential competitors in the environment, competitors for our task goal. So, there are always when we process information, there are always competing information in our in the stimulus flow, the flow of stimulus, right

In today's time we are constantly bombarded with information of various types. 99 percent of them are irrelevant for our purposes for the for most of the time. Our in our system our mental system is well tuned to ignore most of these incoming stimulus. So, that is what that is where we are doing well, because we are able to monitor the conflict. So, if some kind of input is not in our interest, we have to be should be able to ignore that. For that you need a heightened monitoring system and then conflict resolution.

Once you have identified the potential problem you should be able to handle it. So, you there is a resolution. So, processes that aim at eliminating the source of conflict. And

then of course, inhibition. Conflict resolution and inhibition go hand in hand because you have to inhibit those cues that are irrelevant. And unless and until you have inhibited those you cannot find a resolution to your conflict. So, these are the three primary components.

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Now, in experimental setup we are talking about real life, but in the experimental setup we need to create those conflicts, we need to create those scenarios in an artificial way. So, for doing that we have different kinds of tasks that are typically used in order to check the performance of the participants in a cognitive control task.

So, these are called Simon task, flanker, card sorting. These are the ones that are most commonly utilized however, there are many other. And though we will discuss the simple aspect of these task, there are many variations of each of these task that have been utilized in the literature.

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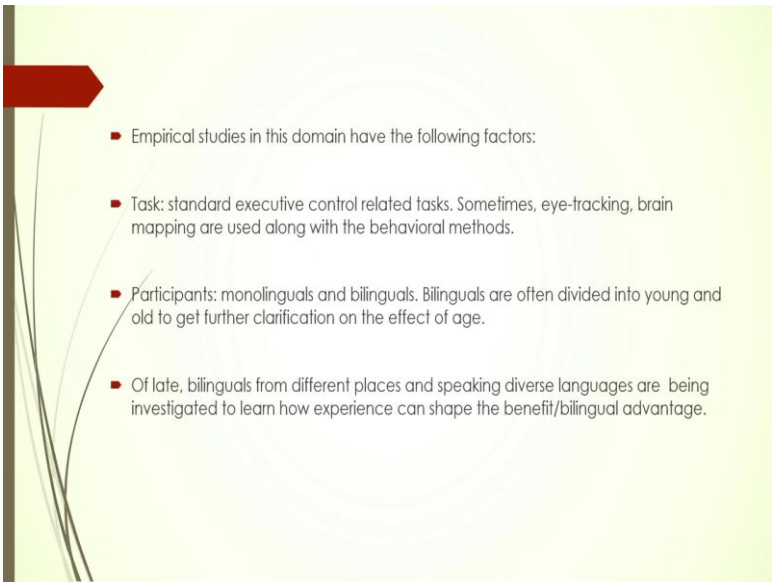

So, let us go one by one. So, Simon task, and before we get into Simon task and flanker and other tasks, what do these task typically have? Typically, if we are talking about Simon task or flanker task or card sorting task or any of these there will be a task. First thing to have is a task. These tasks will look at each task has its own function.

They look at or they target any one particular aspect of our cognitive control mechanism. As we have seen that there are many components of our cognitive control mechanism. So, tasks are created to target any of those or couple of them together at the same time.

So, most of these tasks are behavioral task as in the participants have to give either a comprehension or a production kind of a study, they have to participate and give their reactions.

Simultaneously, sometimes also there are non behavioral task that are non behavioral probes that are simultaneously utilized. So, along with those task we can also have eye tracking and various kinds of brain mapping methods applied simultaneously. And then in terms of participants; because we are looking at the bilingual advantage as in how bilinguals whether bilinguals are better than monolinguals in handling this kind of task; which means we will have two sets of participants. One will be monolinguals the other will be bilingual.

More often than not bilinguals are also divided in the lines of proficiency and age sometimes. So, there are older bilinguals and younger bilinguals. So, younger as in you can have children, you can also have adult and within adults there are a lot of studies that have looked at younger adults versus older adults so that we can get a nuanced and graded understanding of all of these participants. So, these are the typical participant pool in this kind of studies.

And in recent times in last 10 years or so, bilinguals have also been the studies have also taken help from bilinguals from different kinds of language and cultural background ah. In order to answer certain questions that have that arisen out of these studies. We will see them later in the later part of this a module.

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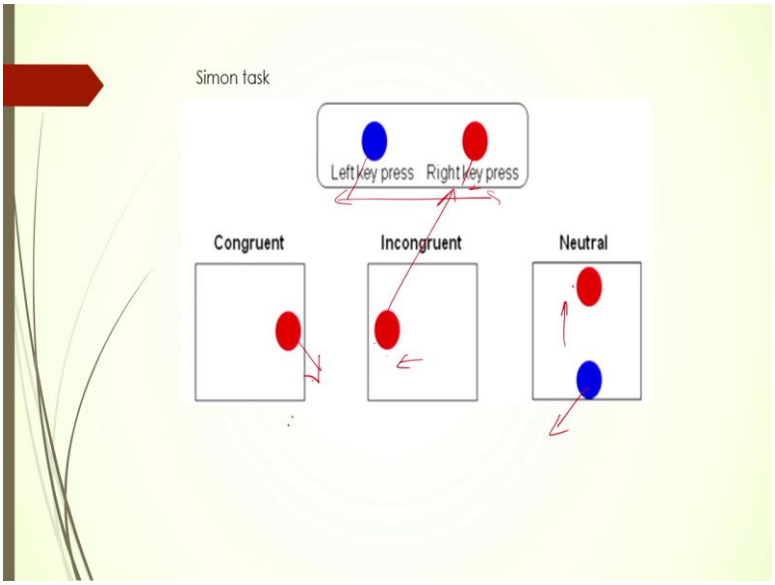

So, let us start with Simon task. So, this is an example of a Simon task. Simon task is a simple task where there will be a cue on the display on the computer screen and the participants have to press a key. Now, the let us say in this particular case there is a red circle and there is a blue circle.

So, participants are told that if you see a red circle then you have to press the right key. Typically, left and right arrow keys are utilized. So, right arrow key for red circle and left arrow key for blue circle, that is the instruction, that is all. Now, in case of sometimes there will be the red will appear on the right side of the screen, sometimes it will appear on the left side of the screen, sometimes it will appear on the vertical orientation.

What is happening here is when the red circle appears on the right, it is congruent meaning there is a similarity between this stimulus and the reaction key. Reaction key is in this case right key. So, right key and the circle also appears on the right side. So, there is a congruency, there is a similarity. The same circle might appear on the left side of the screen. However, remember position of the circle is immaterial. Only the color matters.

However, in this case when the circle appears on the left, we are still supposed to press the right key, but there is an incongruency here. The position of the circle and the position of the response key are in conflict with each other. That is why we call it an incongruent condition. Now, left and right arrow keys are on the horizontal plane and

that is why if the circle appears on the vertical orientation, it does not really matter, it is neutral. This is how Simon task goes.

Now, the logic behind this is that in case when there is when there circle appears on the right and you have to press right key for a red there is no conflict, that is a simple case. When there is an incongruent condition there is a conflict between the stimulus and the response key.

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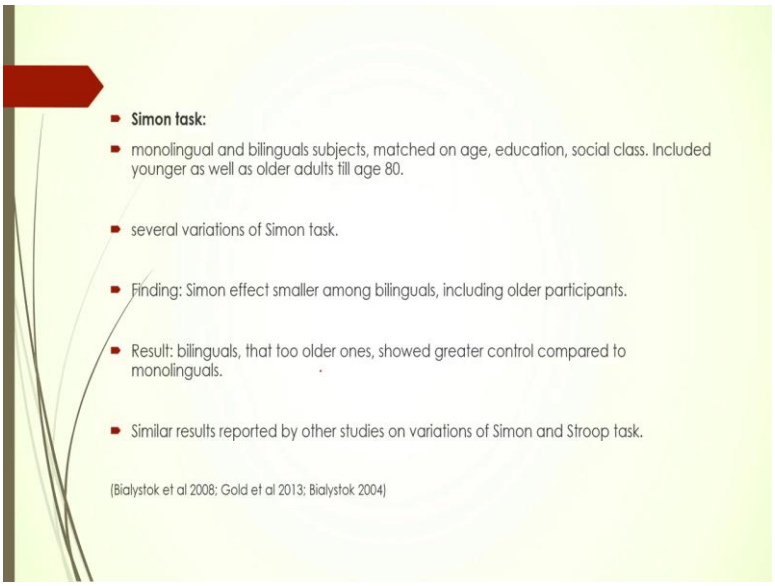

Now, that is why it is a very important task for checking executive control mechanism among the various different kinds of population. Now, there has been a lot of a studies using a executive control the executive control mechanism among bilinguals with Simon task.

There are few that I have mentioned here. So, one of the most important quite a well known study is that by Bialystok in 2008, they had monolingual and bilingual subjects. They were all matched on age, education and social class. These are important factors. If you choose subjects from different age groups, different social class the results might be different, hence we need to control for these factors. So, they were all matched on these.

However, they were bilingual versus monolingual and they also had younger as well as older adults till the age of 80. And this study they had different variations of several variations of the Simon task. And I will say this is the one that we just saw. It is a simple

task, simple Simon task. It can have many variations, but overall, the findings suggest that Simon effect was smaller among bilinguals and including the older bilinguals.

Why is it important to mention the older bilingual separately? Because we have we already know that in case of elderly population cognitive decline starts to take place around 65, 70 or so. So, that is why this age is very crucial. Even the elderly population had smaller Simon effect. What does it mean smaller Simon effect? That in the incongruent condition the bilinguals had not taken much longer.

In typical finding will be in the incongruent condition the time taken to react will be much longer than the congruent condition, which was not found to be the case for bilinguals including the elderly. So, bilinguals the older ones basically a showed greater control compared to monolinguals. There have been many other studies using similar variations of Simon task and they all have reported the same that bilinguals do better.

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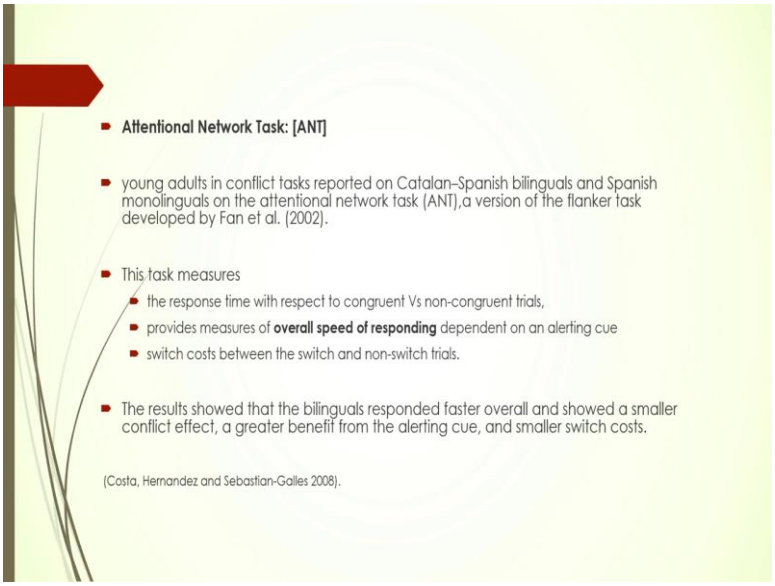

Bilinguals show less Simon effect, less Simon effect as in less reaction time difference between a congruent versus incongruent task. And there has been a consistent finding that older population elderly population typically show a lot of control compared to the elderly monolinguals in these tasks. Another task that has been also used for these is what is called ANT or Attentional Network Task. It is a slightly complex task compared to Simon. It is actually a combination of various things. This is how an ANT task looks like, ok.

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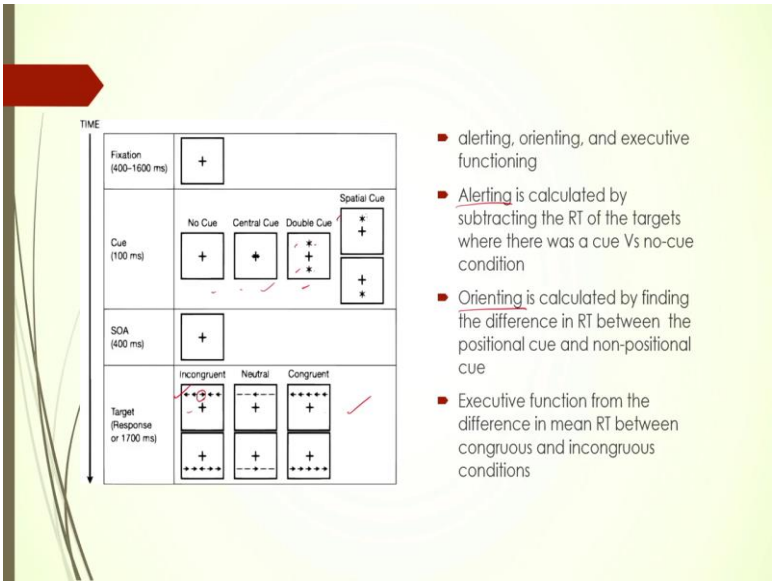

In ANT what happens is that there will be there are cues. So, in the screen the first the screen appears with a fixation cross blank screen and then there may be a cue on the screen. So, the cue may appear in the middle, cue may appear in two different the double cues, central cue and spatial cue.

So, the cues might appear in both these places. Sometimes it might appear only in one place above the arrow or below the above the fixation cross or below the fixation cross. Sometimes there may be no cue and so on. So, these are the possibilities of a cue appearing. After the cue there will be a target. So, this is the target basically, ok. So, this is the target. This is a this is a flanker. Flanker task is a task where you have to check the orientation of the middle arrow irrespective of whatever other arrows are around it.

So, the task is in this case for example, what is the orientation of the middle arrow. In this case it is right orientation towards right and then they have to react. So, here what is happening in this task what happens is that this is the main task. But before that a cue appears. So, there are two levels of inquiry that you can do here. One is how whether the congruent, incongruent, neutral conditions have an effect on the reaction.

Secondly, whether the appearance of cue has anything to do with your cue detection so, with the cue appears and then if the target appears in the same place, does it facilitate or does it inhibit, what are the relationships. So, the relationship between cue and the target and similarly of course the target processing itself so, ANT task is a slightly complex

task and that gives us understanding of at various levels. So, alerting, the role of the cue is to alert, that there will be something that appear that will appear.

So, the cue is simply to alert you. And then after the cue has been there how quickly one can adapt, how quickly one can orient the attention to where the cue is what this also shows. Similarly, and then executive function will be checked by in terms of incongruent congruent division. So, these are the various things that ANT looks at. So, this task basically measures response time with respect to congruent versus incongruent trial that we saw and then overall speed of responding dependent on the alerting cue.

So, if there is a there is a cue how long do you take to relate to it? If there is no cue or if there is a spatial cue versus central cue. So, depending on the cue and the cue detection and your response to the flanker task. And then of course, the switch costs. So, between single simple kind of task or sometimes there are switch task also. So, switch and non switch task difference. So, there are various levels. All of them require a very heightened, very fine tuned executive control mechanism to be in place.

So, ANT when they were employed on monolingual versus bilingual participants, they also showed that that bilinguals did better at every level of ANT task. What are those levels? They were reaction time was overall faster. They showed a smaller conflict effect. They also had greater benefit from the alerting cue.

So, the monolinguals were much slower on picking up the cue as opposed to the bilinguals. So, the when the bilinguals saw the cue they were much more alert and they could react much more quickly to the target cue. And of course, also smaller switch costs. So, bilinguals did better than monolinguals on every single parameter of the ANT task.

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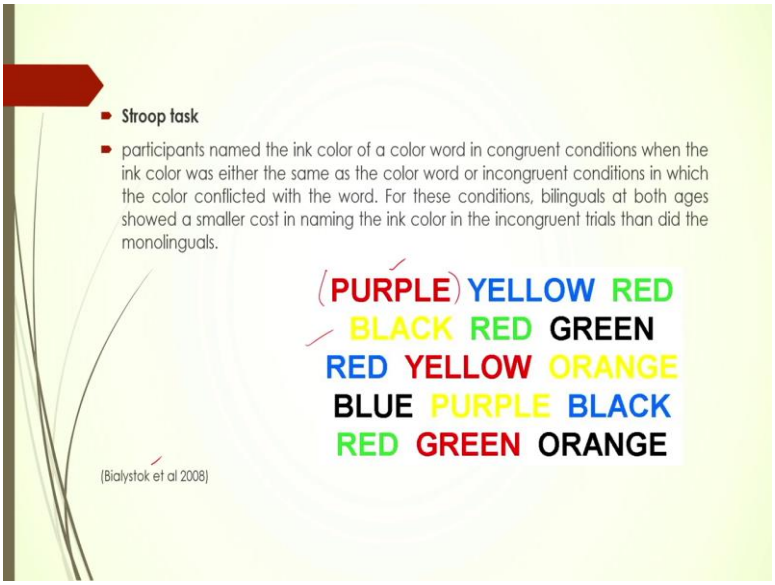

Then another task that has been very commonly utilized this has been used for not only bilingualism, but also many other kinds of studies even within monolingual participants and so on is what is known as Stroop task. Stroop task is this. It is a very simple task, but however, it is a deceptively simple, let us say. So, what happens in a Stroop task is there will be words the simplest version of Stroop task is this. There are many other variations possible. You can actually build in a lot of complexity into this as well.

So, a simple Stroop task is like this. The word name is written in a different color ink. So, purple is written in red color, yellow is written in blue color and so on. The task in this situation is to the participant has to name the color of the ink in which it is written not what the word says. Now, why do as we said that all these tasks are based on some amount of conflict in-built into them.

Here the conflict is the moment we see a written word our system is mental system is built in such a way that we automatically read it. Reading comes reading is an automatic process as opposed to others. So, reading the moment you see purple, you will be more inclined towards uttering the word purple other than saying red, that is the conflict that is in built into this. So, the color of the script rather than what the script says.

As you can imagine the bilinguals bilingual population at various age levels also showed better score compared to monolinguals. We have I have just quoted only one person, but there has been a lot of studies in terms of Stroop task. So, color word incongruent here

also the same congruent incongruent factor is in-built. So, you can write if blue is written in blue ink, then it is a congruent condition. Blue written in red ink will be an incongruent condition. And bilinguals have out performed monolinguals in this task also.

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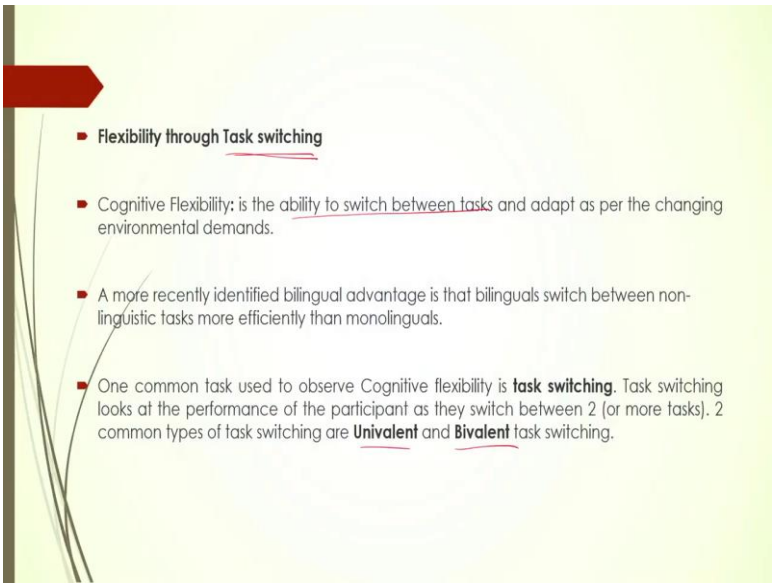

Similarly, we also have a different kind of task different kind of paradigms called task switching. Task switching checks the flexibility, cognitive flexibility of participants through various kinds of task switch. Task switch can be of different types. Basically, the idea is to check the ability to switch between tasks and adapt as per the changing demands, changing demands in the environment, task demands at that given point of time.

So, there are a switch the basic idea here is that to see. So, how do you measure, how do you measure task switching results? Measurement is that when there is no switch versus when there is a switch between two different tasks, do you take same kind of time or do you take more time when you have to switch between tasks. That is basically the measurement of these paradigms. So, there are two kinds of task demands. One is called univalent where another is bivalent. So, univalent and bivalent task switching we will see in shortly.

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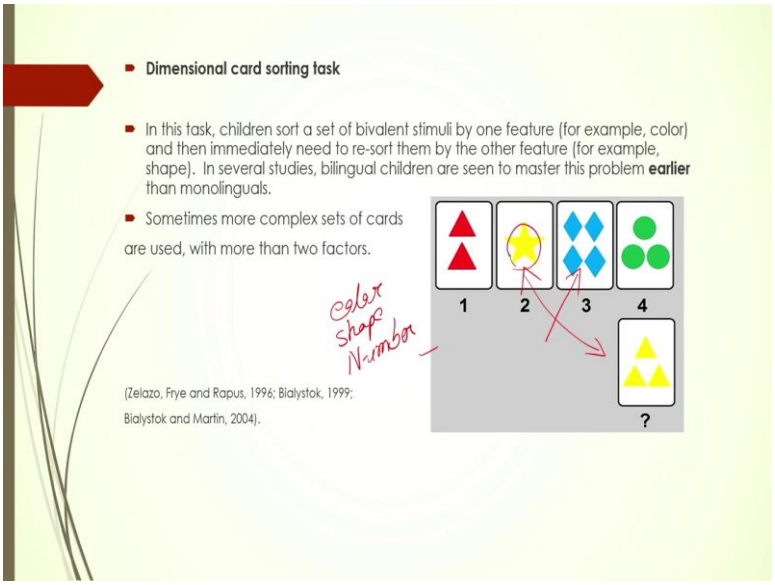

But before that the most simple task switching is what is called dimensional card sorting task. This is used more for children then than adults. For adults what we will see that the different kinds of task switching paradigms are utilized. So, this is a simple dimensional card sorting task. What happens in this task is there are cards, different cards and which would differ in terms of a number of parameters, it can be if it is bivalent there will be two different parameters, if there are, but there can be many more.

For example, that the example set that I have here you see that the cards differ in terms of various factors. So, one factor is color and then the other factor is shape, ok. So, this is a shape, color and then the number. So, cards can be different in terms of a various factors color, shape, number and so on. So, the task typically goes like this: the children are the experimenter will tell children to sort cards in terms of one particular factor. So, one stimuli. So, let us say color.

So, the game starts and they are sorting in cards in terms of color. So, whatever is yellow. So, both of these will go together. So, anything that is yellow will go in one side and the others will be separate. After a few times of playing this the experimenter will change the rule of the game without telling the children. And he will now sort cards on a different parameter. Let us say the number of items present on this. So, anything that has four objects on the card will be sorted together. Like this it goes and it keeps on changing.

The experiments tries to see how quickly children adapt and learn to change from one cue to another immediately. So, depending on how this task has been carried out on various monolingual versus bilingual children participants. And typical finding shows that bilingual children adapt far more quickly than monolingual children in this kind of a task, in dimensional card sorting task.

This is one type of task switching. Task switching because you are switching between. So, the time taken to do only yellow card versus when you the moment you change from color to shape that is the that is the changing that is the changing factor.

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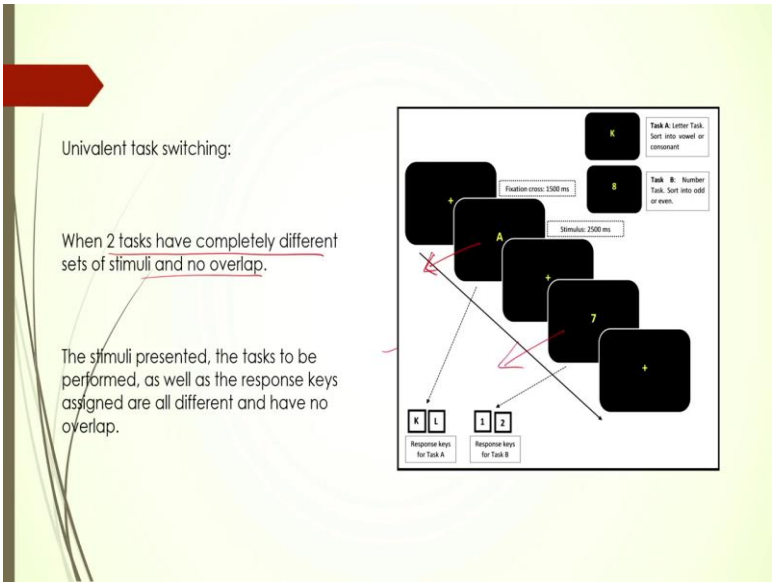

Now, let us look at what is the univalent task switching and bivalent task switching. These are typically used for adult participants. Univalent task switching is a task where two tasks have completely different sets of stimuli and there is no overlap. For example, the task have to be performed as well as. So, there will be no overlap. So, task as well as the response keys are designed in such a way that there is no overlap.

So, in this particular example that I have here, task one is called letter task: sort into vowel and consonant. So, whatever appears they you have to sort them in terms of whether they are consonants or vowels. So, we have this is our cue in one particular case. This can be is it a vowel or is it a consonant. And for that task you have one key that is response key.

Another can be task B is task A is vowel or consonant, task B is number. So, this is the number, whether they are odd numbers or even numbers. So, completely different sets. If you see letters you have to say whether it is a vowel or a consonant, if you see if you see numbers you have to say whether it is odd or even. If this kind of a design is created it is called univalent. Univalent because there are two sets of stimuli which do not have any overlap.

And then you can change. Sometimes there will be letters, sometimes there will be numbers and they will come in there will be all jumbled up and they will change. So, that is why task switching, that is how the task switching is built into this. So, there will be some alphabets followed by some letter, followed by some numbers. And again, some letters and alphabets like this it goes, this is univalent.

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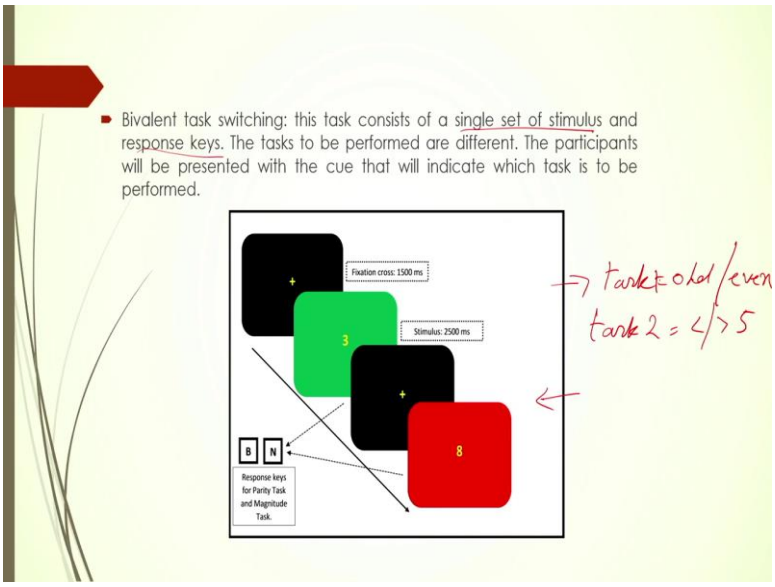

The bivalent task switching on the other hand is slightly more complex, it is because it is a single set of stimulus and response keys however, the tasks are different. The same set of stimulus, but you have to do two different tasks on the same stimulus that is why they are called bivalent. Now, in this case for example, the response keys are same.

However, this there is this stimuli let us say it is number stimuli, only digits 3 or 8, you could have different kinds of task. One is whether it is a even number or odd number, another task could be to check. So, let us say task 1 is odd even and task 2 could be task 1, task 2 could be less than or greater than 5. So, if the number is less than 5 or is it more

than 5. So, you see there is a slightly higher level of complexity that is built into a bivalent task switching.

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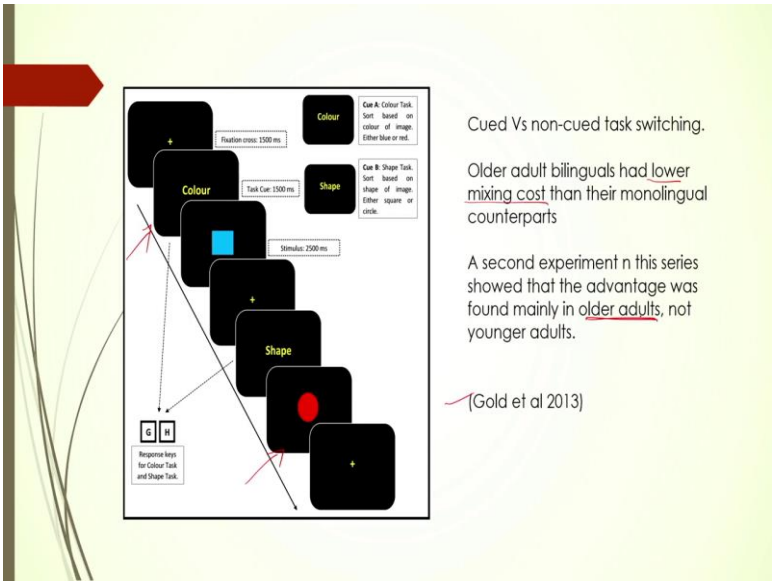

Now, using these different kinds of task switching paradigm there have been many studies checking whether bilinguals are performing differently compared to monolinguals, that is one, that is quite well known that I have quoted here. So, what they had was there can be cued versus non-cued task switching, sometimes there will be a cue. So, there you will have a cue like this color and then you have to also say in terms of shape.

So, the same thing different kinds of color patches in different shapes will come and sometimes you have to sort them in terms of shapes sometimes in terms of color. The stimuli remains the same however, the tasks change, right. So, this is a this is a task that Gold et al did in 2013. And they showed that bilinguals had lower mixing cost, mixing cost as in when there is a mixing one after another that is not a single series.

So, color and shape are coming together one after another a lot of mixing. So, in the that case mixing cost appears. Mixing cost was far lower in case of bilinguals as compared to the monolingual counterparts. Another experiment in the same series they showed that the advantage was found mainly in older adults, but not in the younger adults.

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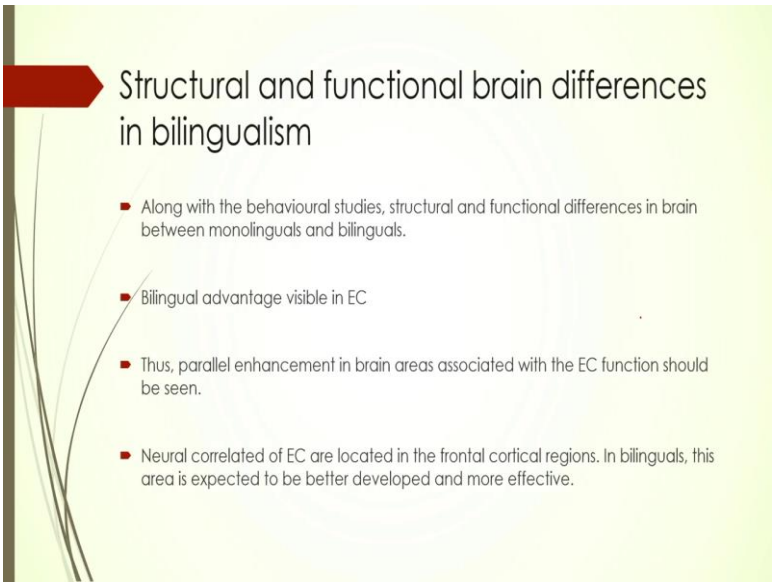

So, these are some of the experimental proof of executive control behavioral tasks that show that there are differences in terms of bilingual and monolingual performance. Now, let us move on to the brain. I mean we have seen we have said in the beginning that executive control functions have been checked in terms of both behavioral and non-behavioral studies. So, let us now move on to non-behavioral studies where we look at the brain different brain structural and functional brain areas.

So, the idea is bilingual advantage is seen in executive control mechanism. Now, if that is the case then the those brain regions that are responsible for controlling executive function should also show some amount of change, right. So, if there is a if the behavioral output shows different then the there should be a comparative comparable parallel difference found in the bilingual brain as well.

So, neural correlates of EC are located in the frontal cortical regions in the human brain. So, in bilinguals this area is expected to be better developed and more effective because bilinguals have higher executive control than monolinguals. Hence those brain areas that are responsible for that control mechanism should also have a better development and better more effective functioning.

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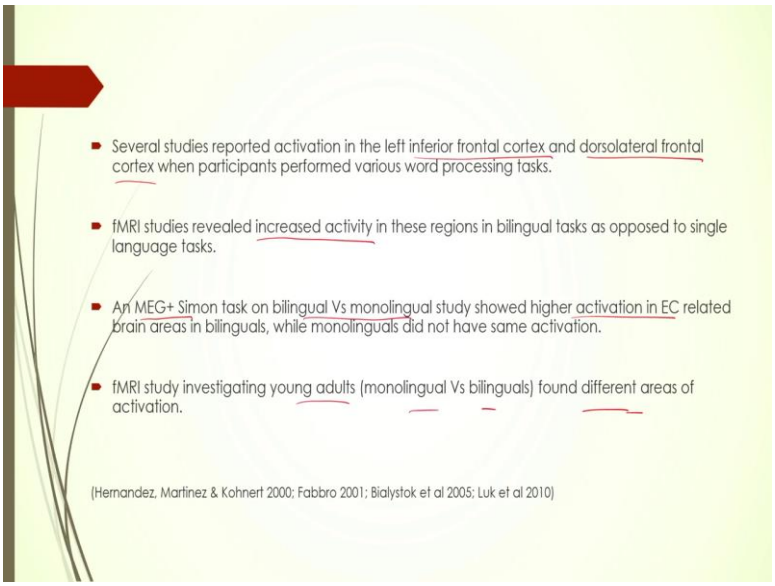

Now, several studies have reported activation in the left inferior frontal cortex and also dorsolateral prefrontal cortex when participant performed various word processing tasks. This is the area which is responsible for executive control in the brain. Various fMRI studies have shown increased activity in these regions in bilingual tasks as opposed to single language task. One particular study which looked at MEG plus Simon tasks.

So, as we said before also that there will be behavioral tasks that are simultaneously, they will also have brain mapping methods. So, there was an MEG and Simon task on bilingual versus monolingual population and they showed that the brain showed that higher activation in the EC related regions in bilinguals as opposed to monolinguals.

Monolinguals did not have comparable activation in those brain areas that are known to be responsible for executive control mechanisms. Similarly, many fMRI studies investigating young adults also found different areas of activation monolingual versus bilinguals. So, in case of young adults also the finding suggest a differential pattern of activation.

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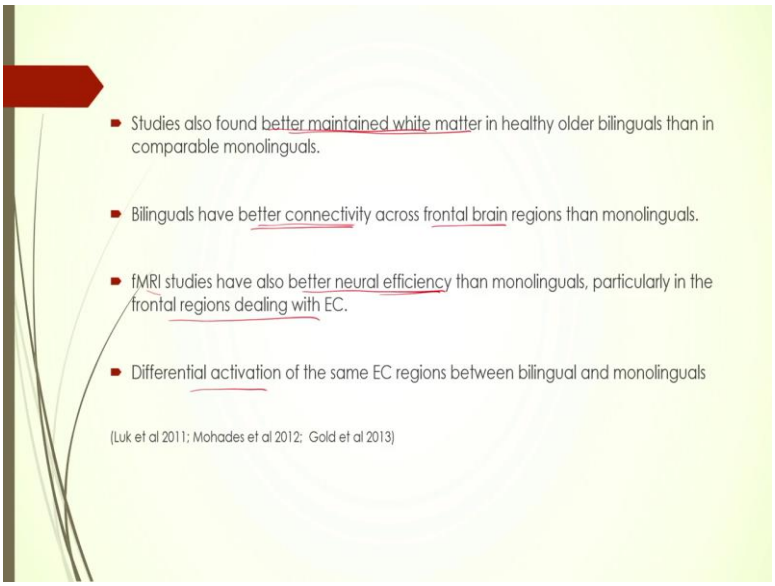

Not only difference at different areas of activation, but also there are structural differences that have been found. So, in terms of structural differences results have studies have showed better maintained white matter in healthy older bilinguals than in comparable monolinguals.

So, white matter have been preserved much better in older bilinguals as opposed to older monolinguals. In why this is important? This is important because in advanced age cortical atrophy starts to set in. What is cortical atrophy? Cortical atrophy is neurodegeneration; neurodegeneration meaning losing of death of brain cells.

We lose body cells all the time; brain also loses its cells. So, in advanced age various cortical regions start losing cells, cells start dying out. So, when they when that that affects that is called atrophy, cortical atrophy.

So, when cortical atrophy affects certain areas which are responsible for important functions that is when we see the person unable to do certain things social cognition, language, various other things. So, that is why preservation of white matter is a significant thing in old age. And in bilingual population we see a better maintained white matter as opposed to monolinguals.

Not only that we also find better connectivity across the frontal region. So, three things already, we see better activation in EC regions in the brain for bilinguals. We also see

better white matter maintenance and we also see better connectivity in the entire frontal brain regions in the bilinguals as opposed to monolinguals.

And then fMRI studies have pointed out various a better neural efficiency than monolinguals particularly in the frontal regions dealing with executive control. So, not only all of these, but differential activation of the same region. So, even when the monolinguals have activated have shown some activation in the EC region in the brain, it is still not comparable with the bilinguals.

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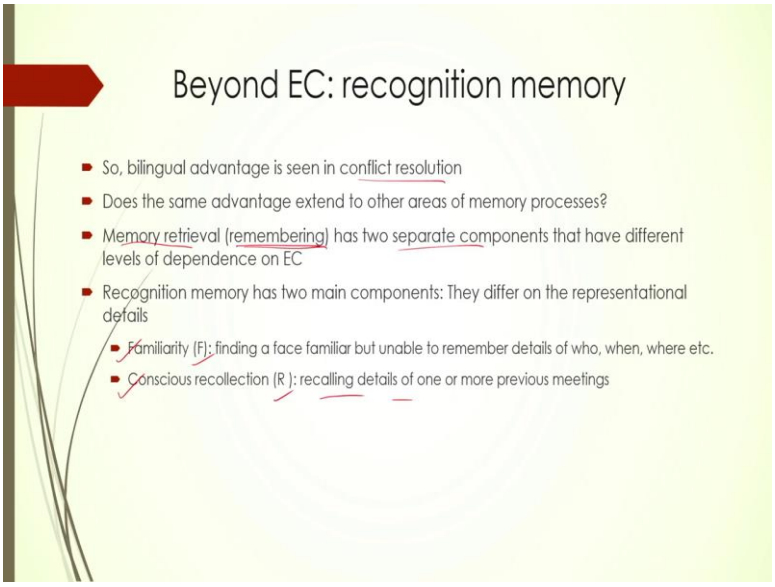

So, in terms of neural signature of bilingualism there are differences at all level, at let the at structural level in terms of white matter, maintenance at functional level with higher activation leading to better connectivity and more well maintained connectivity and frontal cortical region.

Now, moving beyond executive control in these terms let us move on to the domain of memory. Memory also is part of executive control mechanism. So, we are now looking at different kinds of memory recognition memory and working memory. So, in terms of recognition memory also we find some differences.

So, bilingual advantage is seen in conflict resolution that is we that is something we have already seen. Now, the goal that we have now is to see if similar advantages are found in terms of memory processes as well.

So, memory retrieval basically which is which commonly we know as remembering that is called memory retrieval. Memory retrieval has two different components two different separate components, that have different levels of dependence on EC on executive control. Memory as I said is connected to EC. However, there are different components of memory which are some one component is less dependent on EC than the other.

Recognition come recognition memory has these two components: one is called familiarity the other is called conscious recollection in short F and R. F is familiarity something that that is very readily visible. For example, finding a face familiar, but not you know, but unable to remember who the person is, often it happens when you know somebody in a particular context you see him in another context you do not you are not able to place it.

So, if I know somebody as a as somebody who is working in the library a Clerk in the library, I see him in an airport somewhere, I am I will know that I know this person, but it is it takes a bit of time for me to place him where, how and when did I see this person, where did I meet, what are the other contextual information those are missing.

So, that is called familiarity, that is the that is one layer of a recognition memory which is less dependent on the executive control. The other aspect of the same recognition memory is called R or conscious recollection. This is where you are able to recollect each and every detail about the same person about previous meetings and you are basically able to supply more information to yourself with respect to recognition of that person.

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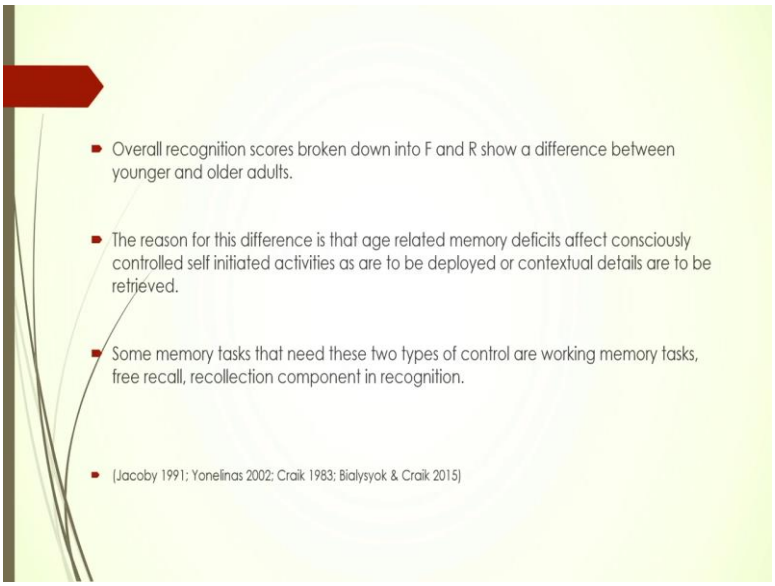

So, this is how the overall recognition can be broken down into F and R scores and this has shown that this has been done lots of lot of work has gone into breaking down overall recognition memory into F and R scores in terms of young and older adults. The reason for this kind of research is that age related memory deficits affect consciously controlled self-initiated activities.

So, as we have seen that in cognitive decline is a common aspect of old age. So, research has looked into which aspect of this between F and R gets more affected. As you can expect R will be more affected in terms of in case of older adults. So, some memory tasks that need these two types of control are working memory task, free recall, recollection component and so on and that is what have been utilized in the experimental domain.

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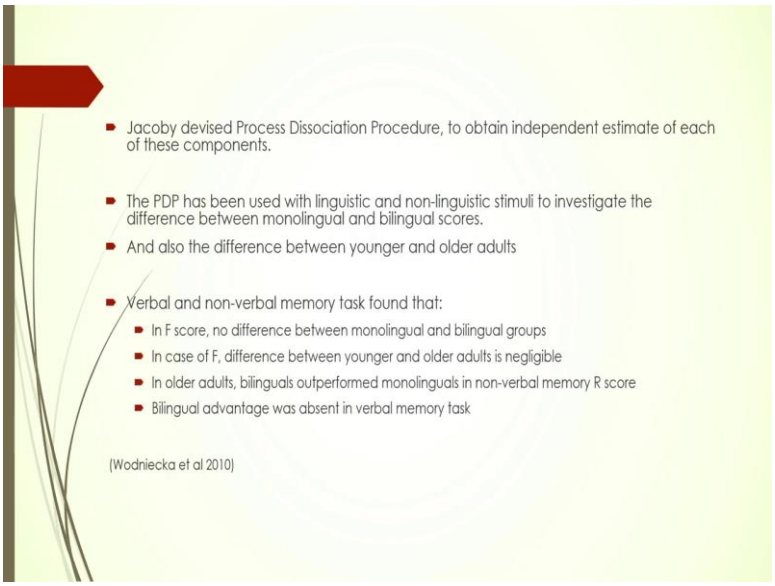

So, the credit goes to Jacoby he devised what is the well-known PDP Process Dissociation Procedure where you can this is a set of experiments which through which one is capable of getting independent estimate each of these two components of recognition memory. So, this has been utilized both with linguistic and non-linguistic stimuli, to investigate the difference between monolingual and bilingual scores as well.

So, this is all an already existing phenomena in psychological literature where one can devise various kinds of experiments based on PDP structure and that will give us the scores for each of these two components within recognition memory. This has already been utilized for younger versus older adults and now this is also getting utilized for looking at the monolingual versus bilingual difference of in terms of who does better in which score, ok.

So, this can use a both linguistic and non-linguistic stimuli. So, basically, they are if you use them if you use linguistic stimuli, it will be called verbal if not it is non-verbal memory task. Now, findings one the one that we are quoting here is done by in 2010. They found that in F score there was no difference between monolingual and bilingual groups. Because F score is the one that is simpler that does not depend much on EC Executive Control.

In case of F difference however, is also negligible between older and younger adults. In older adults bilingual performed better than the monolinguals in R score. When you are

looking at older population, older adults monolinguals did worse than the bilinguals in case of R score. Because remember R score is more dependent on or R memory is more dependent on EC score. Bilingual advantage however, was found to be absent in verbal memory task.

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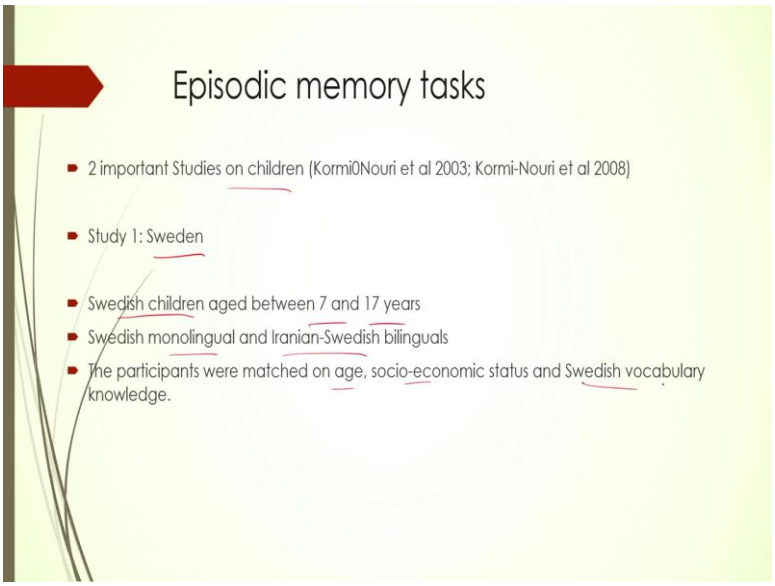

So, then we also have episodic memory which has been looked at length by various researchers. Episodic memory that there are various studies we will talk about only a couple of them, two important studies on children that looked at episodic memory. The one study the study one that we are talking about is by Kormi-Nouri et al 2003 and 2008.

The first study looked at Swedish children aged between 7 and 17 years, ok. So, there were two groups as usual, there was a monolingual group versus a bilingual group. The monolingual were Swedish monolingual native Swedish and the bilinguals were Iranian Swedish bilinguals.

So, those Iranian-Swedish bilinguals had Iran they have spoke Persian at home, then they spoke in Swedish in school and in the other places outside. And otherwise, these participants were matched on age, socioeconomic status and Swedish vocabulary knowledge.

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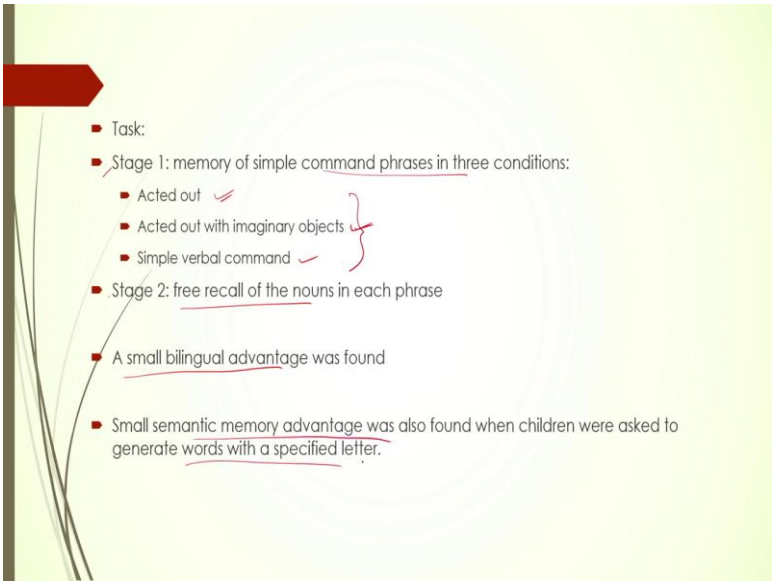

And the task was like this. There were two stages of this task. Task one stage 1 was they had to remember simple command phrases. So, you know pick up the toy, take the spoon, give me the biscuit, pass the cookie something like this. The various kinds of small, short command phrases were there and they had to remember them.

So, they there were three layered difference between these commands. In some cases, they were acted out, in some cases they were acted out with imaginary objects, acted out with real objects, acted out with imaginary objects and sometimes simple verbal command.

There were three types of commands that were shown differing on whether they are acted out or they are just spoken. And then they had to recall, the second stage of the experiment was a free recall of the nouns in each of these phrases. So, this targets our episodic memory, right.

So, what they found was a small bilingual advantage in this case meaning the difference between the monolingual and the bilingual scores were not too too much the difference was very less. So, very small of course, advantage was found, but very less. So, small semantic memory advantages was also found when children were asked to generate words with a specified letter of the same group.

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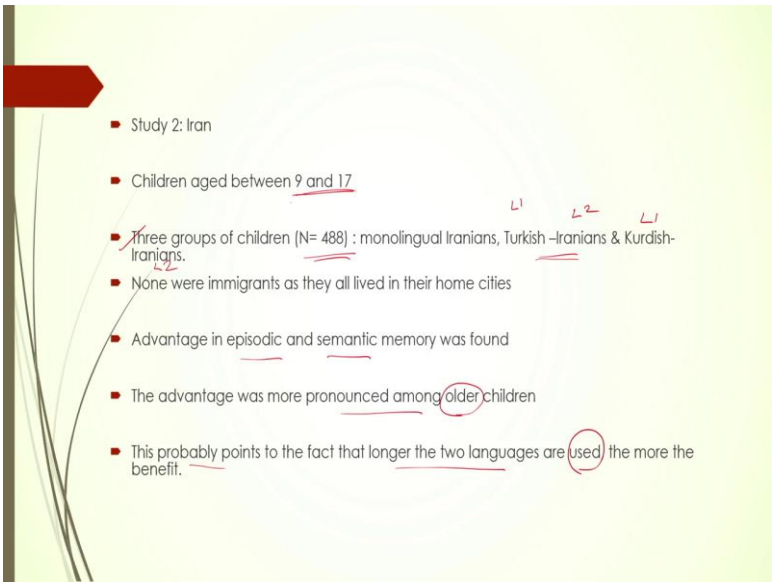

In another study by the same research group, they took this study to Iran and here they had a much more varied group of participants. They had three groups here. The age range remains similar and they had a large number of participants. So, they had monolingual Iranians, Turkish-Iranians and KurdishIranians there were three groups.

So, monolingual Iranians were of course, speaking Iranian at home and outside, the Turkish-Iranians were speaking Turkish at home and Iranian outside, Kurdish similarly Kurdish L1 and Iranian L2. So, this is how the participants were divided it was a large pool of participants with 488 students children.

And in this case however, none of them were immigrants. In the previous study of course, the Iranians are immigrants in Sweden. In this study there was nobody was an immigrant they were all living in their own home cities. So, what they found in this study is that there was episodic as well as semantic memory advantage for the bilinguals as opposed to the monolingual children.

And advantage was more pronounced among older children. This is a very interesting finding from this study if the age group remains more or less same. However, here what they find is that the older children showed a better advantage, better bilingual advantage compared to younger bilinguals.

So, there were difference in terms of age, also in terms of bilingual versus monolingual difference. So, this I this was taken to be pointing to the fact that longer the two languages are used the more the benefit. Studies like this and many others have pointed out that bilingualism itself probably is not a monolith. There are many layers to it, there are many contributing factors that make bilingualism different.

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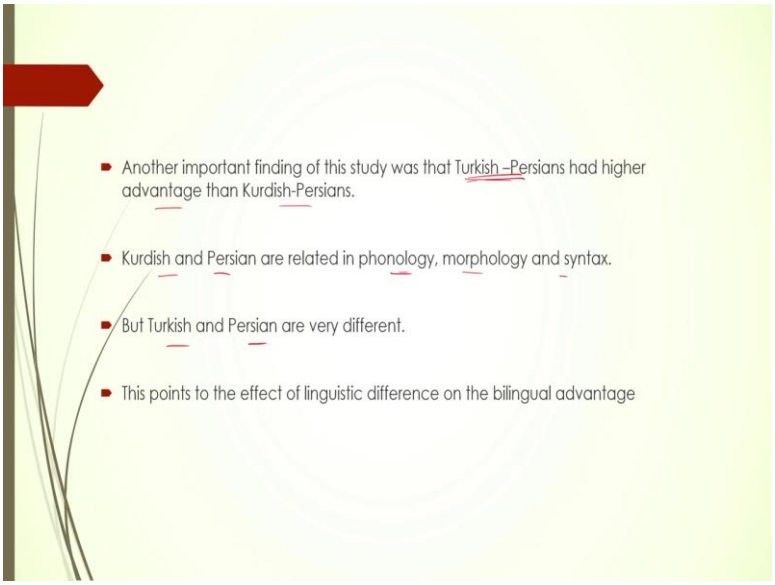

Another interesting finding of this study was that there were two bilingual groups Turkish-Iranian and Kurdish-Iranian. What they found was that these two groups also differed. Both are bilingual groups, but they also differed in terms of the advantage. Why? Because Turkish bilinguals had higher advantage than the Kurdish Persian Turkish Persian speaking bilinguals had higher advantage they compared to Kurdish-Persian.

The reason they have said is that Kurdish and Persian are related languages. They are similar. Similar in they have relation they have related in phonology, morphology and syntax. So, these two languages are closer to each other compared to the Turkish and Persian language pair.

So, in this case in case of Kurdish and Persian they are related languages, closely related languages as opposed to Turkish and Persian. Now, this also has brought out yet another factor within bilingualism within the entire idea of gamut of bilingualism that the linguistic difference can also have an impact on the way the advantage is seen.

The way the bilingual advantage works probably has something to do with this factor as well. So, you already have two different factors, two contributing factors in finding bilingual advantage. One is age that is the longer that you have used your two languages and also the linguistic differences between the two languages.

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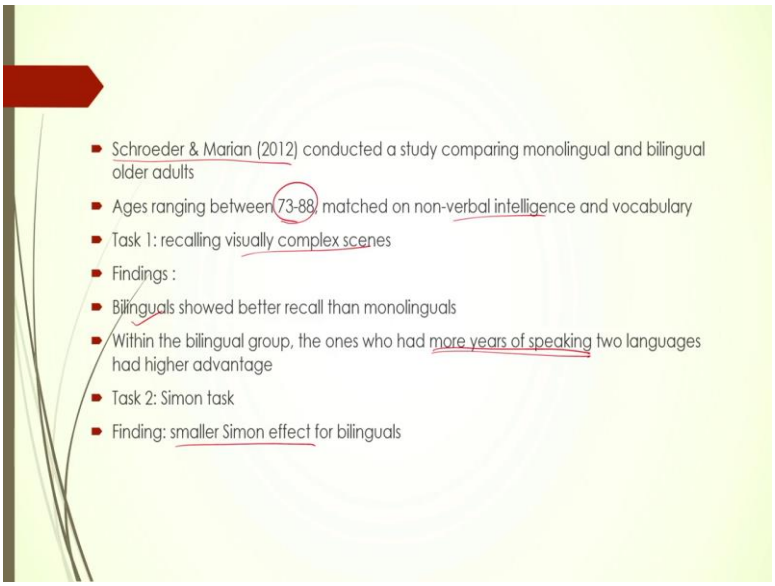

Another study by in 2012 they compared bilingual and monolingual older adults. And this population was you see very quite old 73 between 73 and 88. They were all matched on nonverbal intelligence and vocabulary. They had to recall visually complex scenes. They were shown certain scenes and they had to remember what they saw.

So, the findings as you can expect, they were bilinguals showed better recall than monolinguals and within the bilingual group the ones who had more years of speaking two languages had higher advantage. This study also had a Simon task in-built and they saw the Simon task also had smaller Simon effect for bilinguals as opposed to monolinguals. This is an elderly population where you find this.

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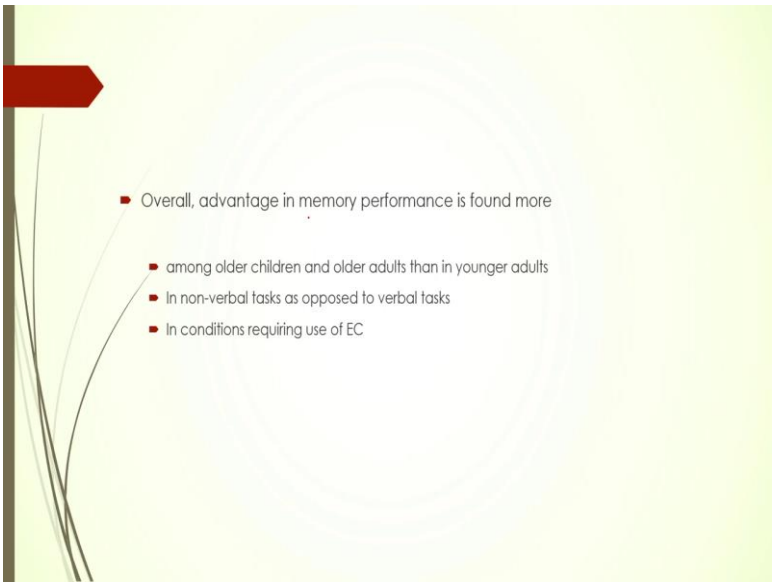

So, overall, in terms of memory performance what we see is that among older children and among elderly population you see better advantage skills compared to younger adults. Similarly, nonverbal tasks were seen to be having higher advantage compared to verbal task and also the conditions that required EC had much more advantage.

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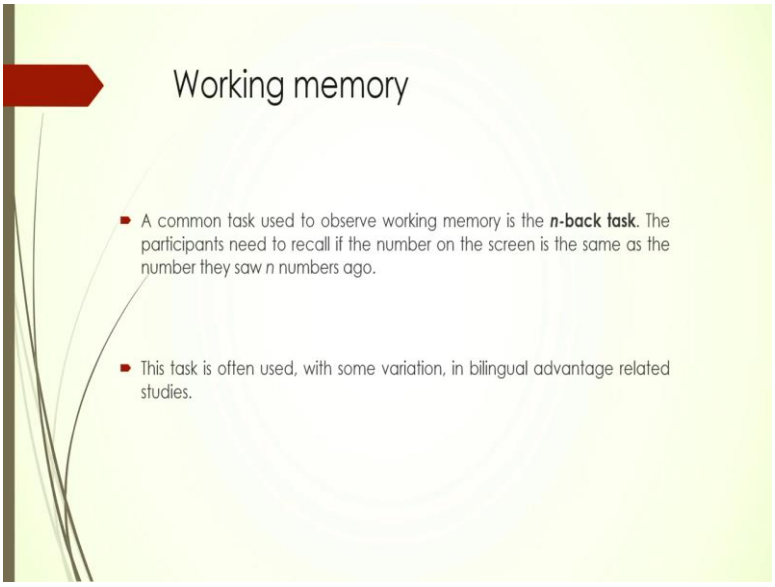

Now, let us move on to working memory. So, we have looked at recognition memory, episodic memory, semantic memory. Now, we are going on to working memory. A common task that utilizes working memory in this kind of paradigms is what is called n-

back task. n-back task is a common task checking working memory performance. In this task the participants need to recall if the number on the screen is the same as the number they saw n numbers ago.

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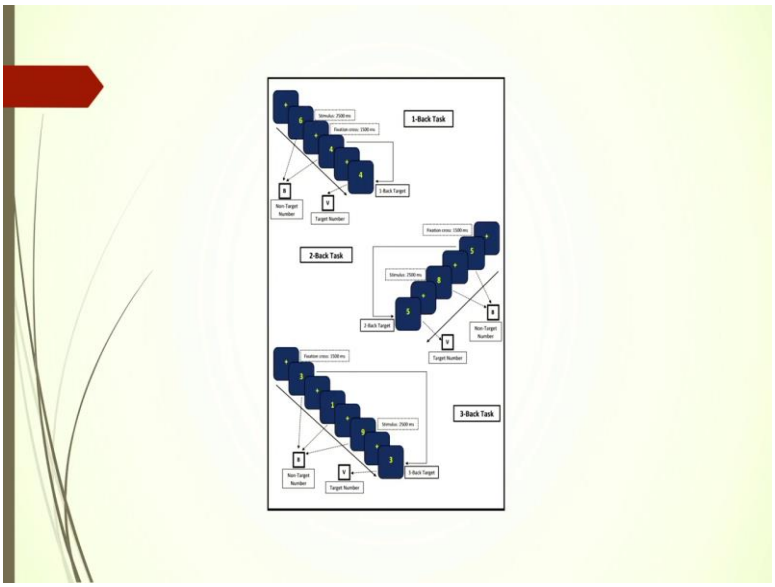

So, these are many variations of these. So, there can be the accordingly that is why n-back, n stands for number. So, this the number that you see right now this is called this is an 1-back task. So, the number 4 here that is the target it has appeared only one slide back. That is why it is called 1-back study.

Similarly, this is 2-back and this is 3-back. So, this number 3 appeared here last time it appeared here. So, this is the task. So, this is this needs your constant working. This is based on your working memory capacity, one has to keep in mind presentations few displays before the one that you have just seen.

So, preceding 6, 7 depending on how many displays you can remember. So, it can be 1-back, 2-back, 3-back. So, as you as the number as the n goes higher it becomes more and more complex. That is why it is called n-back study.

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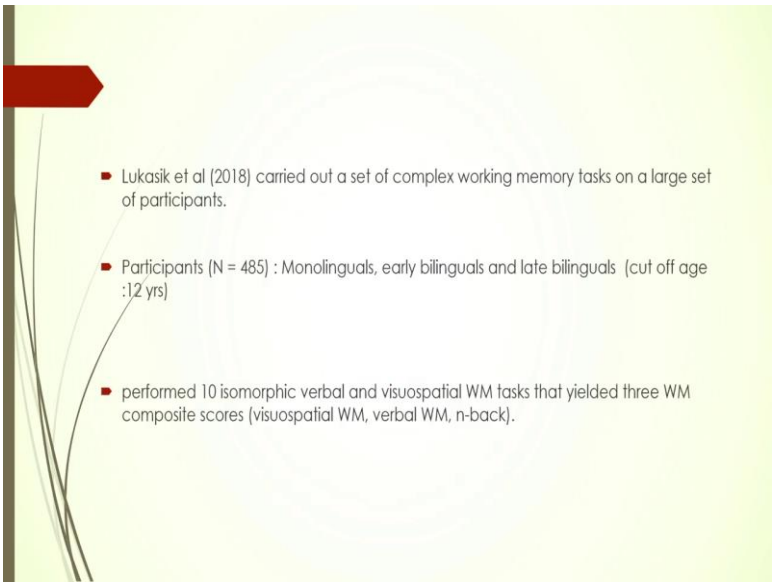

So, recent study in 2018 they carried out a complex working memory task on a large set of participants. This is the number of participants that they checked. So, participants were divided into monolinguals, early bilingual and late bilingual. Cut off age was 12 years. So, early bilinguals were those who learned that L2 before 12 and late bilinguals were those who learned that L2 after 12 years of age.

And they did they this was a large study with a number of experiments, they used 10 isomorphic verbal and visuospatial working memory tasks that had three kinds of working memory scores. There were visuospatial working memory, there were verbal working memory and there was n-back. So, n-back was one of the tasks that they used.

They used three different types of working memory tasks. One was based on visual input stimuli, another was based on verbal stimuli another was based another was simple n-back task.

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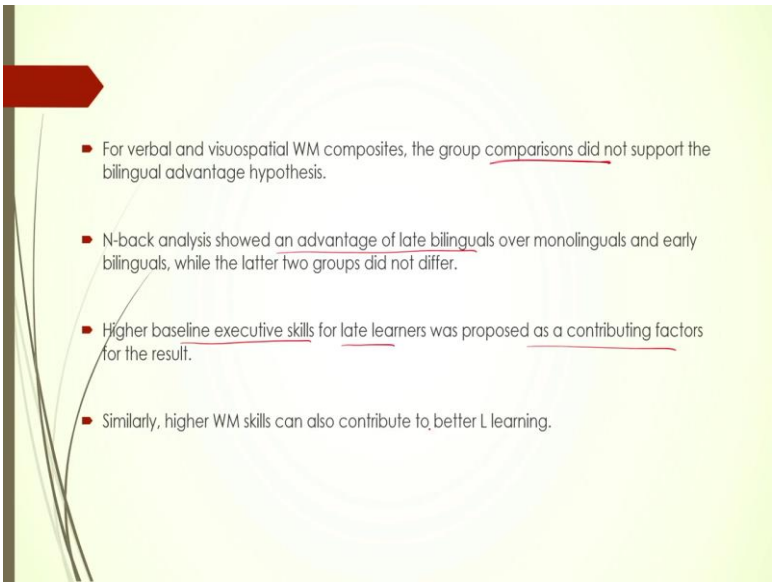

What they saw was for verbal and visual composites there was not much of difference between the monolingual versus bilingual. So, there was not much of data to support the bilingual advantage hypothesis; meaning bilinguals did not do much better. n-back analysis showed an advantage of late bilinguals over monolinguals and early bilinguals.

So, there were three groups monolingual, early bilingual, late bilinguals; only late bilinguals showed an advantage in n-back task. In the verbal and visuospatial tasks on working memory did not show much difference between the groups. And higher executive higher baseline for executive skills also was found for late learners.

Also, this was proposed as a contributing factor for the results. This is how they analyzed the result, that there was a higher baseline executive skill for the late learners. Because they had those executive skills were already placed before they started learning in the language and this is taken as a contributing factor for better language learning.

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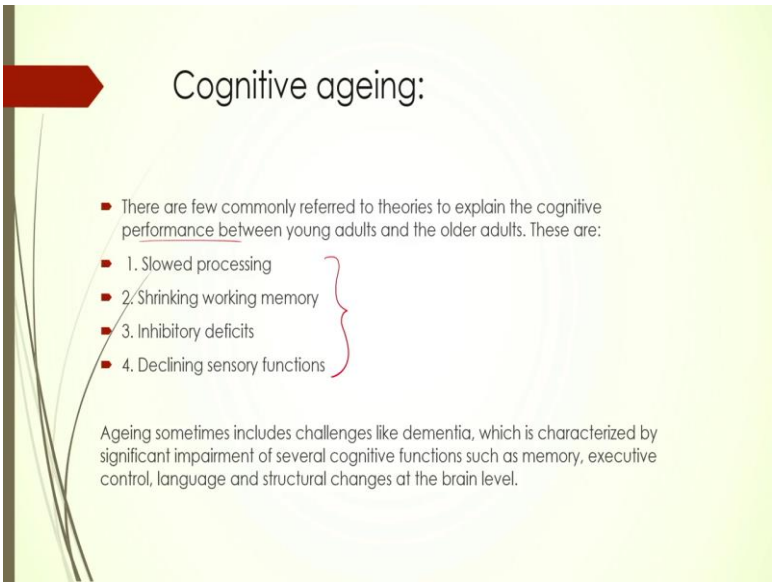

And then of course, is the very interesting domain of cognitive aging. Cognitive aging we will just introduce the idea today and in the next segment we will take it up with experimental evidence.

Cognitive aging is nothing but the slowing down of your cognitive our cognitive apparatus. Cognitive decline is what is aging. So, various few commonly referred to theories that explain the cognitive performance difference between cognitive performance between young adults and older adults. These are the ones these are the pointers.

So, the processing speed goes down and then working memory shrinks. The inhibitory deficits are also found. So, there those incoming stimuli that needs to be inhibited also do not get inhibited very well in older adults. Working memory starts to shrink and sensory functions also starts to decline. So, as a result of all of these there these are the primary differences between older and younger adults that is what together called cognitive aging.

So, in a old age we often find dementia which is characterized by significant impairment of a range of cognitive functions including memory, executive function and language which is very important for us to check. All of these happen because of structural changes at the cortical level brain level.

That we have already seen that cortical atrophy starts to set in. As a result of which various cognitive functions of memory, executive control, language as another thing starts to decline and because of which we see a slower processing speed and various other things. Now, what does it have to do with bilingualism? That is what we will look in the next segment.

Thank you.