Psychology of Bilingualism and Multilingualism
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Hello and welcome to the course introduction to the psychology of bilingualism and multilingualism. I am Dr. Ark Verma from the department of cognitive sciences at IIT Kanpur. I have been talking to you about the bilingual and multilingual brain in the recent lectures and I am going to continue the discussion based on that. Previous lectures we have learned about the necessity of language control for bilinguals which allows them to efficiently manage their two languages, both in terms of production and comprehension.

Now let's have a look at the regions of the brain supporting such a control system. Two important sources of evidence towards the view are actually pointed out. First, bilinguals were actually found to outperform monolinguals even on non-linguistic tasks that required a higher level of executive control. The second is that the performance that bilinguals exhibit between their stronger and weaker languages actually resemble the performance of monolinguals when they were asked to switch between a more difficult and an easy task.

Say for example, an easy task would be word reading and a more difficult task would be colour naming in terms of a strooped scenario. An interesting proposition for neuroimaging researchers would be if they were able to show that the same brain areas were recruited in language control as well as general executive control. This would constitute a most compelling evidence in support of the inhibitory control model of David Green. Now previous research has identified that two regions in the prefrontal cortex actually play an important role in executive control. The regions are the dorsolateral prefrontal cortex and the anterior cingulate cortex.

A range of fMRI studies that have investigated the issue of cognitive control using tasks such as the classical stroop task have actually revealed the shared responsibility between these two areas. Now before I talk more about this, let me just give you an overview of the classical stroop task. The classical stroop task is a task which creates a scenario of conflict. For example, in the traditional stroop task created by J. R. Stroop.

In 1935, you would be presented with colour names written in different inks. So you might be present the colour word green written in green ink, which is a congruent situation and therefore no conflict, but you can be presented with the colour green, the word green written in red ink. The task of the individual is to name the colour of the ink.

Now once you're trying to name the colour of the ink, the pre potent response of reading the word also conflicts with your tendency to name the colour of the ink. This is what is called a scenario of conflict.

This is the kind of scenario that is likened to the scenario of a dual task switching or another response conflict that let's say you have to press, you know, one press with the index finger for one response and the index finger of other hand for the other response and you're confused between which response to take when. So this kind of a conflict scenario is artificially created in order to check how the brain responds to conflict situations. Now the DLPFC actually appears to be involved in implementing and maintaining control, whereas the anterior cingulate cortex seems to be taking care of monitoring performance and signaling the conflict to the DLPFC so that it can increase its level of control to avoid any kinds of errors. Some interesting findings in this regard are relevant to discuss here. For example, MacDonald and colleagues reported that when participants were instructed to name the colour of the stimulus to be presented on the upcoming trial, there was no activity in the dorsolateral prefrontal cortex, but when the participants were asked to read the word on the next trial, it was there.

This finding led to the notion that it is only with the more with respect to the more difficult task that top-down control is actually required and thus implemented by the DLPFC. However, if this were indeed the case, one could liken this finding to the notion that in an unbalanced bilingual where say for example the L1 is very strong and the L2 is not, the DLPFC would be recruited if the individual is forced to use their weaker L2 but not when they are asked to respond in their stronger L1. Another important finding that needs to be pointed out from the study was that the authors did not observe any instruction related modulation of activation in the ACC. Rather instead the ACC responded to the congruency manipulation of the Stroop stimulus. So the ACC actually showed a higher level of activation upon the presentation of an incongruent stimulus than upon the presentation of a congruent stimulus.

Remember what I was telling, if the colour green is written in green ink, it is a congruent stimulus and therefore no conflict is there. When colour green is written in red ink, then there is a situation of conflict and it is an incongruent stimulus. This finding led the authors to suggest that the role of the ACC is to monitor performance and signal response conflict which is then acted upon by the DLPFC. Further, the researchers reasoned that if language control is governed by the domain general emirates of executive control, it would be plausible to expect that the DLPFC and the ACC should also be involved in language maintenance and language switching. Indeed, evidence for the same has been gathered from typically two sources, neuropsychological studies with patients as well as neuroimaging studies with neurologically intact individuals.

Let us look at some of this evidence. Now, Meuter and colleagues actually compared language maintenance and switching performance of an Urdu-English bilingual patient, FK, with bilateral damage to the middle and superior frontal gyri and with that of a control group of neurologically intact bilinguals. Now in agreement with earlier predictions, FK actually showed poor performance on number of tasks that are known to require general executive control. More specifically, the participants were presented with sequences of Arabic numerals 1 to 9 presented in a random order and depending upon the background color, the numerals had to be named in one or the other language. Language switching and non-switching trials actually occurred in an unpredictable manner.

Notably, in comparison to the controls, FK actually made an extremely large number of errors and the exact error pattern observed suggested that he had a specific problem in maintaining and switching to Urdu which was his weaker language. This led the authors to hypothesize that these results would have basically cropped up from FK's inability to marshal and sustain the resources required to suppress the dominant English over their weaker Urdu. These findings, therefore, agree with the earlier suggestions that the instruction and use of weaker language required the involvement of a new task set which was damaged in the case of FK. In another study, Fabbro and colleagues actually examined a prevalent Italian bilingual man who had a lesion in the left anterior cingulate cortex and in the white matter of the prefrontal and frontal areas of the left hemisphere. This patient was assessed for performance in speech production and comprehension tasks and also in forward and backward translation tasks and was found to be perfectly fine with respect to the overall language system.

However, the patient failed to maintain the use of the specified language by the instructor which basically tells us that while the language system is particularly intact and there is no problem with respect to the use of either language, the control is the problem. For instance, when asked to speak in Italian exclusively, the patient could hardly maintain slightly above chance levels of utterances in Italian and inadvertently kept switching to Friulian which was also the case when he was asked to speak exclusively in Friulian. The patient also exhibited pathological language alternation outside the lab even when his interlocutors were exclusively monolingual. Thus, it seems that the patient was unable to sustain the resources to suppress the non-target anguage or alternatively to maintain the target language, which was the case for both of his languages unlike the patient FK in the Meuter study. Further, given the fact that the patient's language system was tested and found to be completely intact, led the authors to assume that the language control network is actually different and slightly independent from the overall language processing network which was intact in this individual.

Similar results were also obtained by Abutalebi and colleagues who also obtained evidence to suggest that pathological within-utterance language mixing could be caused by damage to the left chordate nucleus for their patient AH who was an Armenian woman whose first language was Armenian, the second language English and the third as Italian. Using picturing tasks in all three languages, it was actually confirmed that AH was unable to sustain unilingual output and showed inadvertent switching to one or both of the other languages within a given utterance. These findings led the authors to note that the lesion had actually disrupted a late-stage inverted reval which is the lexical selection from cross-language alternatives and therefore established that the left chordate nucleus is an important part of the network which allows language selection in bilinguals. Based on the neuropsychological studies that we've reviewed so far, three brain regions seem to be critical in managing bilingual language control which are the DLPFC, the ACC and the left chordate nucleus.

Let's look at neuroimaging evidence to this account. Hernandez and colleagues in their studies in 2000 and 2001 and in their study in 2009 actually used functional magnetic resonance imaging to observe neural activity during unilingual and language mixed picture naming by early and relatively balanced Spanish-English bilinguals. As is clear, when their L1 was Spanish and they had all been first exposed to English at a very early age, but at the time of testing they were slightly more dominant in English than in Spanish. These tasks included unilingual and mixed language picture naming blocks wherein the former named pictures exclusively in either Spanish or English and in the latter they switched between English and Spanish in a predictable manner. In addition to the above, in the 2001 study, the participants were administered a pair of non-switching switching condition where they are always produced, you know, the responses in one language in one in the same language also in the switching condition.

So this is a within language task switching kind of a scenario. Here participants were shown pictures of an animal or a person performing some actions, say for example a crawling baby or a barking dog etc. and they were either asked to name the action or the agent. So the switching was between either they have to name the action or the agent. In all three studies, the types of response to produce on a specific trial was indicated by a verbal cue.

For example, in the naming blocks the cue would be say for naming in English, diga for naming in Spanish and in the action and object naming task two for naming the agent and the for naming the action respectively. Now this increased activation in the DLPFC during the language switching condition actually led to the conclusion that switching between languages in picture naming actually involved an increase in the general executive control as compared with the amount of executive processing required for

unilingual picture naming. Additionally, the within language task pair of 2001 study where they were asked to alternate between naming the object and naming the action, the similar activation of DLPFC was actually observed. The researchers basically concluded that because in the within language switching task the questions were relatively easy, therefore it did not recruit the involvement of executive control areas, more specifically the DLPFC. Finally, in another study by Hernandez and Meschyan in 2006, they tested a different bilingual population which included all late Spanish-English bilinguals who had started to learn English after the age of 18 years.

When tested, the Spanish was clearly the dominant language among these individuals. Now these participants were made to name the blocks of pictures in either L1 Spanish or L2 English while FMRI scans were being made. The scans showed that increased activity in the DLPFC was observed during picture naming in their weaker language as compared to their stronger language. Now so far we have actually seen mainly production tasks, let us move to some kind of comprehension tasks as well to understand whether these areas of language control DLPFC, ACC and the caudate are also recruited in comprehension studies as well. So, in an FMRI study, Crinion and colleagues examined the activation patterns in the brain for a group of Japanese-English bilinguals and a group of German-English bilinguals.

Here the participants were asked to make semantic relatedness decisions to printed word targets that were preceded either by a related or an unrelated prime, and these prime and targets could be belonging to the same language or could be coming from different languages. Interestingly, both of these participant groups actually showed activation in the left caudate nucleus as per the related manipulation, that is, the left caudate was less activated in related conditions as well as in the unrelated condition. However, when the prime and target were from different languages, the level of activation in the left caudate was same in both conditions. So the activation in the left caudate you can see is being manipulated by related, unrelated where the person is evaluating and also it is much more active when the targets and the prime are from different languages, which also required some degree of control. So these findings led the author to conclude that the left caudate actually plays a very important and a universal role in monitoring and controlling the language in use.

And these kind of results were also supported in another study by Abutalebi and colleagues, where he actually examined the neural correlates of language switching during comprehension using event related fMRI. These participants in his study were Italian and French bilinguals who were asked to passively listen to narratives that contain sudden and improbable switches to the other language. In this study also, the areas that were found activated were the left ACC, parts of the left DLPFC and the left caudate.

Moreover, switching into the more exposed and practiced L2 actually showed a less extended activation pattern in direct comparison between the two types of switches showing that switching into L1 selectively engaged the caudate and the ACC. So you can see here that depending upon the task requirements, the activations in these areas actually, you know, change.

Now, these findings led these authors to conclude that the brain's executive control network subserves both language production as well as language comprehension function and that selective activation in the ACC when switching into a less exposed L1 probably hinted at the level of enhanced control required to process the less practiced language. In summary, we can say that the results from both the results from both the neuroimaging and the neuropsychological studies suggest that the areas of control are actually the same with regard to both comprehension and production, which are the DLPFC, the ACC and the caudate, especially from the left hemisphere. This is basically what I wanted to share to you about language control and the neural regions underlying language control. I will move on to a different topic in the next lecture. Thank you.