

Fundamentals of language Acquisition

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Week 11

Lecture 055

Lec 55: Proficiency

Hello and welcome back. This is Lecture 5. Until lecture 4, we have been looking at the interconnection between language areas in the brain and language development in the case of infancy. And then we took the discussion all the way to bilingualism and how early and late bilinguals may have differences in terms of their functional localization in the brain. Early bilinguals have a different functional localization compared to late bilinguals, and this differentiation is not only present among bilinguals but also among monolinguals. In the case of monolinguals, the distinction is between the early words and the late words. So, the words that are learned early will be processed in the sensory system with help from the sensory motor cortex, but the words that are learned later will have more dependence on the prefrontal cortex. Some of these studies we have already looked at; some of those findings we have discussed. Now, the age of acquisition has been discussed already. So now we will move on to proficiency and a few more domains.

So, in the case of AOA, we have seen that it plays an important role in the processing of language in bilinguals, but this is not the only important predictor. Another important variable here is proficiency. So, this has also been pointed out by various other researchers looking at the aphasia data. So, in the case of bilingual aphasia, there are different ways and different patterns of aphasia itself, as well as different recovery patterns for L1 and L2. So, based on that, Pitre's rule pointed out the fact that expertise in the language may have a role to play in determining which language will be affected in case of aphasia, as well as which language will be easier to recover after aphasia.

Let us say that after a stroke, once you have aphasia in one of the languages, which language will you recover from faster? So, Pitre's rule states that expertise will be an important predictor here. So the stronger the language with which the affected person is

more familiar, the more resistant they will be to damage. So in modern times, we use the terms proficiency and expertise, but we mean the same thing: that the stronger language means the more proficient language. In the modern era, studying expertise as an important part of the cognitive mechanism started with Adrian de Groot. He was a chess player himself, and his pioneering experiments also involved chess; he looked at chess players and how they, what they do, and what cognitive mechanisms they actually utilize while playing and while looking at a chessboard, and so on. So, there are many studies; for example, one of his most important studies looked at how novice and expert players study the chessboard. So, what do they do? How do they do things differently? Because both the novice and the master players, know the rules of the game. They also know that by looking at the chessboard at a particular stage of the game, they already know how that stage was arrived at. So, both know the things similarly. However, the master approaches the game differently than a novice.

So, what happens there is what he studied. So, masters differed from the novice not only in remembering a greater number of chess pieces, but they could also recall the gist of the position very quickly. This is one of his most important findings. So, this was one of the first pieces of research that looked at the processing differences between experts and novices in any field. Now, they bring this idea to language. What are the domains that reflect differences in proficiency? So, proficiency plays an important role in how well you handle a particular scenario. Depending on how proficient you are at playing chess, your strategies will be different. Similarly, in language, there might also be some kind of parallel, so that is what we are getting at. So, in the case of language, what are the domains of language that reflect differences in proficiency? This was the question. So, Marta Kutas and her group looked at this question. One of the very first studies to check brain activity differences among monolinguals and bilinguals with different proficiency levels was carried out by them. It was an EEG study. The stimulus was like this. There were paired sentences and something like this. "The reporter whom the senator attacked discovered the error", "The reporter who harshly attacked the senator discovered the error". So, these are complex sentences and this was given. So, the probe question was, the task was to answer who discovered the error. So, in the first case, "the reporter whom the senator attacked" , so in the first case it is the reporter. In the second sentence, "the reporter who harshly attacked the senator discovered the error". So, the answer to the question will have an impediment within because of the embedded clause here. So, sentence 1 is more difficult compared to sentence 2 since it uses a less conventional layout, thus leading to a higher cognitive load. Both sentences are similarly complex, but the first one is a little more complex because of the unconventional layout. The subjects were differentiated on the basis of a verbal working memory test. So, poor performers had a higher LAN effect, which is late anterior negativity.

We have talked about this before. It is a negative going wave appearing between 250 and 600 milliseconds over left central electrodes. So, they found that poor performers had a higher LAN effect. Now, since both sentences were grammatically correct, the LAN effect is understood to reflect the effortfulness of the processing. So, if you need more effort, then the LAN signal will give you an idea of which one was more difficult to process.

So, there was no difference in processing in the second sentence, only in the first. Poor comprehenders, when they discovered the verb inside the clause "who the senator attacked," showed higher LAN than good comprehenders. So, that is the finding that they reported. Also, they had a large, slow positivity that continued until the end of the sentence, showing effortful processing because of the very structure of the sentence. Many such studies have also been carried out with respect to keeping proficiency in mind, providing this kind of sentence and difficulty level, changing the difficulty level, and so on. Similarly, another study by Neville's group found shorter waves for both LAN and P600. We have already seen P600 before with respect to age of acquisition as well, so among high proficient monolinguals compared to low proficient speakers, while processing sentences like "Timmy can ride the horse at his farm" and "Timmy can ride the horse at my his farm." So, the second sentence is not grammatical, and they were looking at the LAN and the P600 effects. And they found a difference between proficiency levels. So, high proficiency versus low proficiency, even within the monolinguals, have different neural signatures; that is what we mean by proficiency having a neural signature.

So, how do you know if somebody is highly proficient? This kind of signal will be seen in his case; in the case of low proficiency, this kind of signal will be different. So, that is what our dependent, output variable is. So, the basic finding from all such studies is that highly proficient speakers can register errors immediately, and once they have registered them, they can repair them quickly without too much cognitive load. So, the main finding is that proficiency equals efficiency in processing. The higher the proficiency, the more quickly you will be able to find out and rectify the error. So, in the case of a grammatically complex sentence or an ungrammatical sentence, if you are reprocessing, the reanalysis of the sentence will be done similarly. So, the low proficiency will have more difficulty in processing there. A 1995 study reported the case of a Bolivian woman who had migrated to the US at the age of 10. At 19, she started showing signs of seizures, along with naming difficulties. So, the CT scan revealed brain damage in the left temporal and parietal lobes, which are critical for language.

Then, surgery was performed to remove the malformation in the area. So, a large area in the left hemisphere of this lady was removed. What was found out is very interesting: before surgery, she scored 19 out of 30 on the Spanish naming test. She is from Bolivia, so Spanish was her mother tongue, and she left Bolivia at the age of 10, which means the second language appeared much later in life, after 10 years. So when she came to the US, English was the language that she spoke before the surgery.

The surgeries happened after 19 years. So, by that time she had already been speaking L2 English for 9 years, but for the first 10 years of her life, she was a native speaker of Spanish. Now, so that they had a naming test done before the surgery, her score in L1 was pretty good at 19 out of 30, but in the second test carried out after the surgery, she scored 32 out of 60 in Spanish and 44 out of 60 in English. Now, what does it mean? This suggested that the mentioned areas of the brain affect familiar language more than the L2, which is familiar as in the L1, because the left part of the left hemisphere, in the case of the left parietal and temporal lobe, was removed. So, we can safely say that that area was probably more responsible for processing the L1, the more familiar language, which is Spanish in this case. As a result, her score in Spanish went down after surgery. Similarly, there are also many other studies with similar kinds of findings. Another domain that has also looked at this relationship between the brain, the neural signature, and L2 among bilinguals is the domain of control mechanisms. So, control mechanisms, when you are bilingual or multilingual, let us say you are a highly proficient bilingual or multilingual, then there is a control mechanism that we need to put in place in order for us to control which language to use and which language not to use. For example, I am multilingual. So, right now I am using my L3; English is, let us say, my L3. So, now I have to subdue my L1, L2, and then other languages as well. So every bilingual exercises a control mechanism in order to decide which language to use and which not to use. So, this is what comes under the domain of the executive control mechanism. Executive control has these four domains: inhibition, monitoring, selective attention, and flexibility.

Flexibility includes updating information. So, depending on the environmental cue, we update our information structure, and as a result, our reaction and behavioral output as well. So, inhibition is an important part of the executive control mechanism. Now, separate brain regions are responsible for these activities. So, the question is, do monolinguals and bilinguals use the same brain areas for this function or not? So, if you are bilingual, do you use the same areas that a monolingual uses for these purposes? So, in some studies involving these two groups, similar activation patterns were visible.

So, the areas that we are mostly interested in for this kind of study are the ACC, the anterior cingulate cortex. This region is responsible for impulse control and decision-

making, among other things. In a combined Stroop and fMRI task, both monolingual and bilingual groups were found to activate the same region. Now, what is a Stroop task? The Stroop task will be, for example, the classic Stroop task, which is something like this.

Let us say I write the word "black." Now, the task is to say, let me give you an example, a classic example of the Stroop task. So, let us say this is the task; this is the Stroop task. The participants are asked to look at the words and mention the color of the ink, not the color that is mentioned. Now, stroop task, what stroop task does is, stroop task checks your inhibitory control mechanisms. The goal here is to suppress the automatic reaction.

Automatic reaction is that it is a well-established fact in the literature that when you see something in writing, our first reaction, which is almost involuntary and is automatic processing, is to read it as it is. Now the task here is to suppress that, inhibit that reaction that involuntary reaction rather focus on the color of the ink. Now, in the first case, the color of the ink is black; sorry, the word is black; the color of the ink is red. In the second case, the word "black" is written in black ink. Now, this is obviously the more difficult task; this is the easy task. So, this is called the Stroop Effect. So, when you have stimuli like this, you will have a higher Stroop effect. The Stroop effect means that your reaction time will be higher. So, you will take more time to say the name of the ink. As you saw just now, I also made the same mistake. Most participants will make some mistakes. So, the error rate will be higher in the first case. The error rate will be lower in the second case. In the case of the correct answers, the reaction time will be higher. So, this is a classic Stroop task. In this particular experiment, they used the Stroop task and fMRI together.

So, as the participant was taking part in the Stroop task, fMRI was also being conducted on their brain. So, both monolinguals and bilingual groups are found to activate the same region which is ACC. Why ACC? Because ACC is responsible for impulse control. So, you have to control responding black in the first case. Similarly, in a different study using the Simon task, the caudate nucleus was activated for both groups, monolingual and bilingual. Simon's task is yet another task that checks impulse control, executive control, and so on. Similarly, another study in 2015 compared the grey and white matter volume in lifelong monolinguals and bilinguals. And they found something very interesting: that bilinguals showed more frontal lobe white matter. So, for a lifelong bilingual, the chances of having more white matter in the frontal lobe are higher.

So that is what they found. Also, monolinguals showed decreased white matter in the temporal lobes, but bilinguals did not. So, bilinguals did not show any decrease in the white matter in the temporal lobes, and they showed an increase in white matter in the

frontal lobe. So, there was a serious difference between the bilingual and the monolingual participants in this study. So, when they administered the Stroop task on them, the Stroop task we just discussed correlated white matter volume with task performance. So, depending on the higher the white matter volume, the better the performance of the participants; that is what they found. Now, these areas of the brain are responsible for executive function. So, those areas of the brain that are responsible for executive control seem to have higher gray matter, and those people also performed better on the task. Hence, the argument is that bilingualism alters brain physiology. As I started this lecture with the idea that language actually interacts with the structure of the brain, we are not only talking about functional localization, but language use, specifically bilingualism, contributes to structural changes in the brain. Some data have also come from the resting state studies, as in when the participants are not doing anything, but simply resting, and the brain studies will look at how the brain functions during that time. So, research in this domain tries to examine the functional connectivity inherent in key areas when there is no explicit task at hand. So, how have the connections been, and how is the functional connectivity present even when they are not doing any kind of action? So, the key question was whether experience-induced neuroplasticity modulates functional connectivity in bilinguals or not? It seems that this is the case. So the results suggest the same. So, what the hypothesis was found to be verified by the data. So, for bilinguals, the functional connectivity will be different compared to monolinguals.

In an interesting study, a more recent study from 2017, the ACC sulcation pattern was studied in monolinguals and bilinguals. The method used is called brain morphometric analysis. The participants also performed a flanker task for executive control measures. All of these tasks are executive control measures, such as Simon, Flanker, and so on. The main question was whether the sulcation pattern was related to performance in the task. So, what they found out was that ACC sulcation variation correlated with task performance. Bilinguals had more sulcal variation and did better than monolinguals. A usual finding is that bilinguals typically do better than monolinguals in most tasks that require executive control. So, based on this finding the authors proposed that early neurodevelopmental mechanisms depend on environment which in turn can affect cognitive efficiency. So, these and other findings have led to what is the most debated topic of the bilingual advantage, but that is for another day.

L2 acquisition also has, as we have just seen, bilinguals seem to have more white matter in certain areas. So, that takes us to a domain that discusses bilingualism, which is the constant use of two languages that has an effect on the very anatomy of the brain itself.

So, that kind of, in real terms, literally messes with your head in a good way. So, one influential study in 2021 by Liu et al. reported that gray matter volume decreased in the left anterior cingulate cortex and right inferior frontal gyrus after L2 learning for one year.

This study was carried out on Chinese speakers of English. So, English was the second language, and just after one year of using L2, anatomical changes in the brain were found, and a decrease in gray matter volume was observed. So, gray matter and white matter change depending on how long you have been speaking your L2. So, these changes are connected to language control abilities in bilinguals, as I was just mentioning; when you speak more than one language, the inhibitory control process is automatically activated. So, there has to be a control mechanism in order for it to be able to effectively use one language or the other in a given scenario. So, the control mechanism automatically appears when you speak more than one language, and these changes with respect to grey matter and white matter are connected to the executive control mechanism. So, as a result, this is a very common finding among bilinguals. But this study was among the very rare studies that actually looked at it from a longitudinal perspective. So, they checked the participants before, and they checked them after 1 year, and they actually saw a gradual increase. So, findings such as these point towards dynamic structural adaptation of brain regions in relation to L2 acquisition. So, based on these findings there have been models that have been proposed, models of brain adaptation due to bilingualism. These models suggest that the structural brain adaptations are dynamic and can be expressed as cycles of local tissue increase and decrease depending on the duration of L2 learning.

So, we have already seen that in some cases the white matter will increase, in some other areas the white matter will decrease, in some cases the grey matter will increase, and so on. So, based on these findings, there are a few theories that have been proposed; we will discuss only two models. These models are based on the idea that this is a dynamic kind of relationship depending on how long you have been speaking the L2; we will see certain kinds of changes, and those changes are connected to the control mechanism that we utilize. So, one of the models is the bilingual anterior to posterior and subcortical shift model proposed by Bialystok and others in 2017. As per this model, the duration of exposure to L2 has an impact on the dependence on ACC for processing it.

If you have noticed in all these studies, many of the researchers actually focused on the region of the ACC and how it gets activated by bilinguals, monolinguals, early versus late, and so on. So, dependence on ACC has a direct correlation with the duration of the L2 exposure. That is what this model has incorporated. As the learning duration

increases, reliance on the frontal cortical region decreases. So, in the beginning, when you are speaking an L2 and you are not very good at it, your proficiency is not very good, so you need a lot of effort. So, effortful processing will be seen in the prefrontal cortex. As the time of exposure increases, say from 1 year to 10 years, the dependence on the ACC will decrease because the process is no longer effortful, hence the decrease. and an increase in subcortical regions like the left caudate and the posterior regions like the occipital lobe. So, there will be a shift from the ACC to other regions, including subcortical regions and the posterior cortical regions, like the occipital lobe. Another model that has actually built upon the previous model was proposed in 2020. This takes the idea a little bit further, and they propose three different stages within this.

So, the previous model says that there is a shift from dependence on the ACC to the subcortical regions. This model states that there are actually stages through which this shift occurs. They call it the initial stage, then the consolidation stage, and the efficiency stage. So the initial stage is where you have the most dependence on the ACC, and then over a period of time, when they are efficient users of the language, that is the last stage; that is the third stage. So, more recent findings suggest that bilingual experience also has direct implication for changes in the subcortical regions. So, we started with the cortical regions; initially, we talked about Broca's area, Wernicke's area, and the three major visual, motor, and sensory cortices; now we have come all the way to the subcortical regions as well. Not only are we talking about subcortical regions being responsible for language acquisition and processing, but now we are saying that bilingualism and the length of bilingual experience have an impact on the changes in the subcortical region. So, we have come a long way; researchers have, you know, the findings. the developments of research in this domain have really gone through a lot of changes and paradigmatic shifts. And now we know that being bilingual also has a non-linear effect on the basal ganglia and thalamus. So, not only the cortical region but also various subcortical regions, including all of these. So, the thalamus, the basal ganglia, and so on. These are more recent findings; this is a very influential paper from 2023 that has looked at this. So, this is not a linear kind of effect; there is a non-linear effect.

So, this is not only dynamic but also non-linear; the impact is non-linear. So, to sum up, in this module, we looked at the relationship between language acquisition and brain structure. Some of the cases, mostly in the context of early language acquisition of L1, show near simultaneous developments in language as well as brain maturation. In the case of L2, some changes are seen in the cause-effect relationship between these two. So, as language develops, as your proficiency in L2 develops, and as the duration of exposure to L2 increases, there are certain changes—actually, some causal impacts on the brain structure itself. So, this is an evolving field; we are still getting very exciting results from

different groups that are looking at it. So, the field is getting richer every day, but we have to stop somewhere. So, this is where we wrap up this module. Thank you very much.