Cognition and its Computation
Prof. Rajlakshmi Guha
Prof. Sharba Bandyopadhyay
Biotechnology and Bioengineering
Indian Institute of Technology, Kharagpur

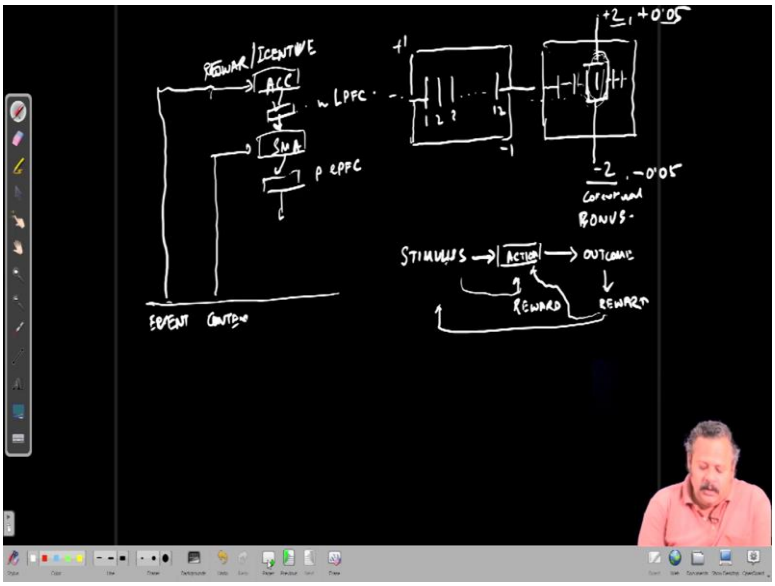
Lecture - 55
Frontal Cortex in Decision Making

Welcome. So, we have been talking about Decision Making and today we will continue on that discussion from now from the point of view of the parts of the Prefrontal Cortex and how they are involved in the decision making process. So, as we have mentioned earlier ultimately all the decision making processes are about stimulus cue which can be of a variety of kinds then the stimulus may not even be entirely physical in nature.

So, I mean can be something that is of effective value also and so, the those stimuli are ultimately processed to get the relevant information depending on the situation and that could be very fast for that it is essentially at the level of the sensory motor processes, then it could be contextual for a particular situation only and then it could be a episodic where the control is more temporally extended and requires memory and or even long term memory that is that can be involved in the decision making process.

So, if we consider the colchicine model or cascade model of decision making so, we will start with the example of how the supplementary motor area.

(Refer Slide Time: 02:04)



And the anterior cingulate cortex, the two regions that are involved in the processing of the reward or incentive value associated with the stimulus that influences the sub regions of the prefrontal cortex or the SMA influences sub regions of the prefrontal cortex, in this case is the posterior lateral prefrontal cortex and in this case is the medial lateral prefrontal cortex.

So, from one case in one case the incentive value is obtained from the context or the current stimulus and the other case the incentive value is calculated from an episodic or rather an event that is relevant for this particular episode. So, with FMRI studies that have looked into the supplementary motor area and the anterior cingulate cortex in humans where the FMRI signals can be correlated with the amount of activity in that particular region of the brain, we know from these experiments.

So, here people were asked to play a game where they had they could either if they had 12 kind of choices to make or 12 things to do in one particular block. So, 1 2 3 up to 12 and if they did all of them correctly they would get plus 1 dollars or they would get 1 dollar and if they made any one wrong they would lose 1 dollar. And so, they are doing this repeatedly over many trials and on top of this there were 1 out of those 12 randomly can be cued to be a special trial and that is in the sense that let us say the random leads.

So, they that particular trial is cued and there the reward or loss based on whether they perform that particular trial correctly or not, could be much higher like a plus 2 or a

minus 2 for only that trial. And so, the idea is that with this they were trying to dissociate the contextual part of decision making. This is a current context that a cue is telling me a stimulus in coming up on the computer screen on which they are looking to perform the task a stimulus comes on and tells them ok this is a high value trial and that if you do correctly you get 2 dollars and if you lose you get you lose 2 dollars.

If you do incorrectly you do lose 2 dollars and. So, these are the high value trials and then these are bonus high value trials and the there were bonus low value trials also which were plus 5 cents or minus 5 cents or 10 cents does not matter it is much lower than the episodic 1 dollar value.

So, with this they while the people the subjects were performing this task where there are 12 trials with 12 different tasks you know all the trials correct 1 dollar winning and anyone wrong minus 1 dollar with embedded bonus trials which could be of high value or low value. So, they wanted to in with this experiment what they showed is they could tease out whether something some particular structure is involved in the episodic decision making versus something that is involved in the contextual decision making.

That is if signals were unaffected by the this particular context and get involved in the decision making then there would be more on the based on the episodic value of the stimulus and stim. And the structures that are responding in a correlated manner based on plus 2 and plus 0.05 and usually the one and if they responded specifically to the rewards with the bonus trials.

And not to the other trials episodic episodically then they would be involved in the contextual process and. So, in exactly this is how people showed that the ACC and SMA are involved in the respectively in the episodic part of decision making and in the contextual part of decision making.

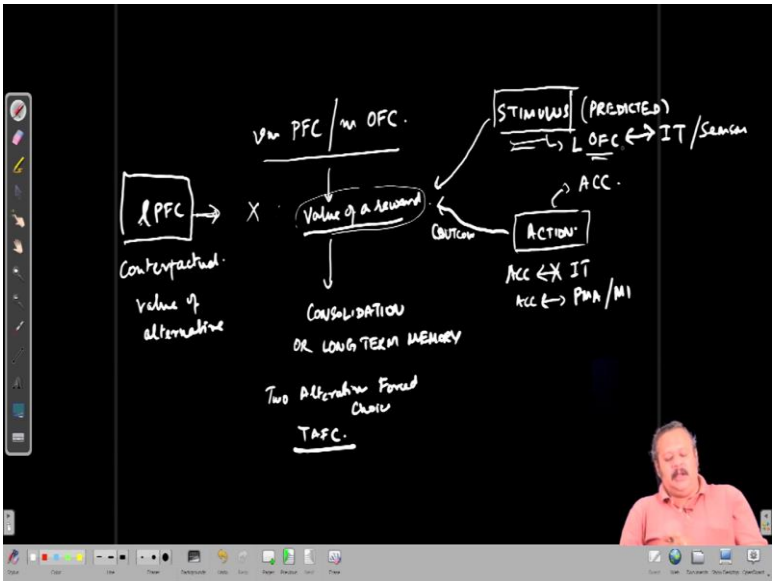
Because the ACC bold signals were unaffected and they would be equally high throughout the 12 trials and would not change for the high value or low value bonus trials whereas, the SMA is specifically increased for the bonus trials and they would increase in a correlated manner based on the amount of the value or the value of the reward at that context for plus 2 it is larger for plus 5 cents it is lower. And so, this directed the idea that ok these are explicitly separated out one is episodic and one is in the context of the current situation.

So, now based on many other studies we have a much better understanding of very specific locations involved in the decision making process which is itself in itself a huge area of study and in terms of discussion is also not possible to cover our in our course and could even be one course itself based on the current literature, but if you if we will try to streamline it down to a few things and that is as we have been saying that you have a stimulus.

Then you get the relevant information and based on that you take an action based and this is guided by some sort of reward value and this has an outcome which is the current reward based on which we can update our ideas of how a stimulus is going to predict a reward or how an action is going to is correlated with the reward and we update our decision making accordingly in future trials. And so, this is I have essentially streamlined down the entire cascade model into this serial process sort of thing.

And different regions are known to play different roles in this whole process.

(Refer Slide Time: 10:39)



And what we know is that the ventromedial PFC and the medial OFC, these two regions are heavily involved in reflecting the value of a reward. So, this is essentially this value is something that is not quantifiable in terms of how we understand value like monetary value it is not a direct relation to shape like that, but there is an order in terms of something is more preferred than the other and so and the different items can have a different levels of value.

And this is essentially computed and represented and actually also recalled and also helps in consolidation of long term memory of a particular reward and its value. So, this goes into the consolidation also or into long term memory. So, that much later on for the same kind of situation we know what the value of the outcome is or the reward is and by recalling from long term memory.

And the whole thing is mediated by the areas in the medial part of the prefrontal cortex the an OFC being a part of the prefrontal cortex, but a specialized location both of those are involved. So, now the value of a reward can be from as we have said the reward can be predicted by your stimulus or the reward could be the outcome of an action that we have taken based on the decision as we have been saying.

So, the current understanding of this idea is that the stimulus reward associations the stimulus the actual cues the stimulus reward associations occur in the lateral OFC and the action and outcome associations are occurring in the anterior cingulate cortex. So, there is a dissociation in terms of the stimulus outcome association and the action outcome associations and we are learned in the distinct regions.

So, how do we know these basically based on FMRI studies and lesion studies under tasks where as we saw before where it is a reward guided task where the stimulus predicts the size of the reward. So, the size of the stimulus predicts let us say the size of the reward let us say a circular patch appears then you know that this is the reward if you press the correct button and you know as the size increases the reward would be larger.

And so, these aspects correlate well with the value of reward and in and the signal in the lateral OFC from even single neurons are involved are understood to be representing this correlation or the value which is related to the stimulus. So, also the lateral OFC is very heavily connected with the sensory regions that are involved finally, in object recognition.

And so, there are inputs onto the lateral OFC from the IT cortex that is from the region where we do visual object recognition as you know and also other kinds of object recognition from other areas from the auditory areas also there are projections directly onto the lateral OFC.

Similarly, all in the rodent we know a huge projections are there from the olfactory system onto the OFC in fact, the OFC is the first cortical region where the olfactory system projects. And so, the value of a particular stimulus and this association is represented in the lateral OFC there is plenty of evidence now that corroborates with this idea.

Similarly, the action outcome associations are shown from lesion studies as well as experimental studies with FMRI as well as single unit studies in animals where we know that this region is involved in producing the action and the signals are correlated with the value of the reward or the outcome of a particular action.

And so, this region the ACC region lacks heavy inputs from the IT. So, this region has strong inputs from the IT sensory regions; however, ACC has sparse inputs from the IT region ah, but it is heavily connected the ACC is heavily connected on the other hand with our motor pre motor area and M 1 that is basically to produce an action and correlate with the outcome. And remember these are reciprocal in the sense that ultimately we require to modify the representation based on the reward to get the proper association going. So, it is these are generally reciprocal connections.

So, this is what we see in terms of a correct reward choice that is we are looking at the we are looking at the stimulus and we are making a correct decision. So, as we have seen before when we studied the reward system it is actually what is causing us to learn is the error prediction the prediction error of reward in reward.

And so, that is what drives the learning and creates the associations. So, that is essentially represented in the lateral PFC and this is the counter factual decision, this is the counter factual decision making region and what do we mean by that is the lateral PFC actually signals when a decision is made the signals here actually correlate with the value of the alternatives.

So, these we know from experiments primarily in an two alternative forced choice experiment two alternative forced choice experiments where the person or subject or the animal has only two choices that is either to make take the course of action a or the course of action b and nothing else and it has to do one of the two. In that kind of situation it is easy to actually look at the value of the alternatives and if there are multiple

other choices how that is reflected in the lPFC is probably distributed among different populations of neurons there.

So, here what the lPFC shows is actually exactly the opposite of what the medial PFC here shows with the value of a reward so and the value of the alternative. So, these are more or less opposing each other and if we make errors then the size of the alternative that was there, the reward size of that alternative actually is driven by the lPFC signal.

That is the larger the lPFC signal the more probability the person or the subject has of switching their action or switching their choice in upcoming trials, that is it is basically providing the cue by signaling the high value of the alternative. That ok, you missed this high value.

So, if there is a comparison made of the current reward obtained in a situation versus what the lPFC is telling that this was the alternatives value then that if that is higher and the higher it is the more probabilities that the animal or the subject in human case switches in the next trial of the same kind of stimulus. So, that tells us that these are all intricately linked together in terms of producing a decision.

So, now there are many subdivisions of all these regions that we have talked about that are specifically and highly are involved in decision making in a more specialized way which is beyond the realm of this course or scope of this course. So, for one aspect we will look at like for example, in a social decision making context we have ensembles of neurons in the OFC that predict rewards for social related behavior or is that the behaviors that are not related to social activities.

So, the ensembles of neurons are distinct that govern the connection between the stimulus and reward this reward association while people have shown this the lateral OFC has different ensembles of reward of neurons in the different cases. Similarly, memory being involved in decision making is also a highly specialized exactly how memory is involved those require much further specialization into the different structures, how it is recalled and so on.

So, in conclusion in an abstract sense at least the idea is that for decision making we have to associate a stimulus or the sensory cues with a particular action with a particular reward prediction and so take a particular course of action to reach there and the anterior

cingulate cortex in a more extended time extended manner is involved in taking the action and getting associated with the outcome.

And so, the anterior cingulate cortex also has a persistent activity because of the extended duration of time required to get the action outcome associations going. Similarly, the lateral OFC the stimulus predicting a reward also can require extended time to finally, correlate with the value of the reward.

So, the finally, whether it is action outcome value or it is stimulus outcome value, the value of a particular reward is reflected in the PFC and that is modulated or corrected based on a different context all the time with the counter factual signals from the lateral PFC.

So, with this we are closing on our discussions on all the different aspects of cognitive computation I mean cognition and computation and so in the next set of lectures we will be discussing some of the open problems in this field.

Thank you.