Foundations of Cognitive Robotics
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Lecture - 14

Good morning students, welcome to the course of Foundations of Cognitive Robotics. We have reached the last lecture in this series of foundations in the cognitive robotics; where we will specially focus on some experiments and experimental efforts that we are carrying out at IIT Kanpur.

So that, you will be able to know that if you have to develop such robotic systems what are the general experimental setups that are needed. And also you will get yourself familiarized with the different types of experiments that are possible in this direction.

So, our focus today will be a few case studies through the experiments related to the field of cognitive robotics.

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Well, we have chosen the first important part in terms of the experiments in the field of child robot interaction. Now, you know already about Human Robot Interaction or HRI which is a common, very common you know topics in robotics, where the robots basically interact with adult human beings. And both ways the robots basically learn from the adult human beings and also it helps in many cases like for geriatric applications, it helps adult human beings in terms of different types of let us say you know requirements, functional requirements for elderly people.

The point of child robot interaction is quite unique. Generally, for child robot interaction we choose children of the age of 3 to 11 and as you can see here that there is an interaction between a Nao robot and a child so that is taking place. So, the cognitive development for this type of kids is generally immatured and it is still at the developing phase. When we have discussed about the human brain, we have talked about this aspect.

Now, one very important thing is that much unlike the adults a child does not foresee a robotic system as a simple mechatronic device. It actually imposes a significant degree of human like nature. In fact, we have a term for it, it is called anthropomorphisation in their mind map. So, the perspective of a child and 3 to 11 year children we are talking about, the perspective of a child towards the robot is totally different than an adult human being and that is a very important point that we have to keep in our mind in child robotic interaction.

Also that this is fundamentally different from the adult robot interaction is, because children are not just small adults, their neuro physical, their physical and their mental development are actually ongoing. So, this also makes a challenge in terms of the human robot interaction. So, that is why the applications that I will show you today in terms of cognitive robot development will be mostly will be actually in the field of child robot interactions. So, that is one important.

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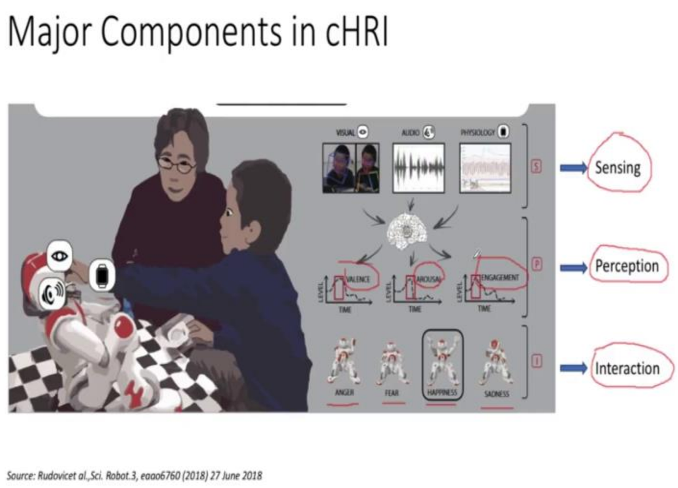

Now, the major components in this interactions you know if you consider that how a child is interacting with a robot, it will be in terms of different types of sensing both from the child’s point of view. Somatosensory sensing of the robot as well as the visual and audio related sensing and that is somewhat true for the robots point of view also.

It should be able to then interact with the audio visual and other types of sensory systems. Sometimes touch is also included and then the other component of this interaction is in terms of perception, how the child is perceiving the robot and how the robot is perceiving, how is it making a differentiation between a child and an adult and of course, in terms of the interactions.

These interactions you can think of bringing you know aspects like that the robot shows anger, fear, happiness, and sadness and these how the child is perceiving all these emotions, emotional perceptions as these things are happening. And of course, these perceptions we can quantify it in terms of things like valence, arousal, these are all certain aspects of measuring the emotions and also engagement.

So, from the visual data that the robot gathers we should be able to actually measure this level of perceptions and accordingly, we should be able to find out the relative importance of various types of interactions.

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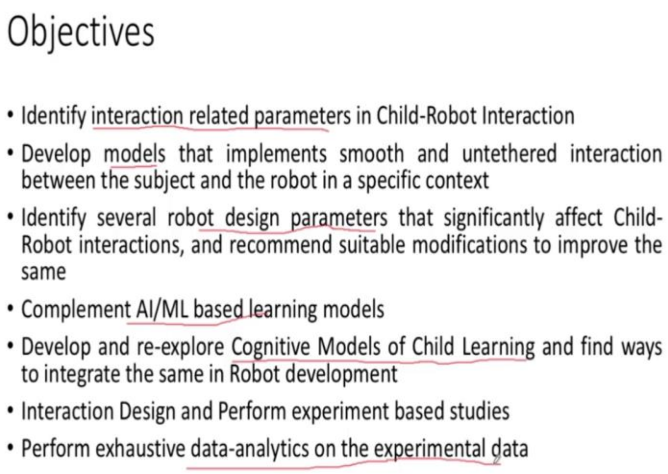

Now, the objective of these experiments will be first of all identifying this interaction related parameters that is very important. And develop different models that would implement smooth and untethered interaction between the subject and the robot. So, model development; identifying several of the robot design parameters; let us say the interaction speed, rhythm, interaction pattern whether it is visual, audio, audio based or somatosensory.

So, identify these robot design parameters that affect child robot interactions and try to come out with recommendations for suitable modifications to improve the same. And complement the AI and machine learning based learning models, because in this case the robot has an embedded intelligence.

Develop and re-explore different cognitive models of child learning and find ways to integrate the same in the robot development. Interaction design and perform experiments and perform exhaustive data analytics on the experimental data. So, these are the kind of objectives that we keep when we design experiments related to child robot interactions.

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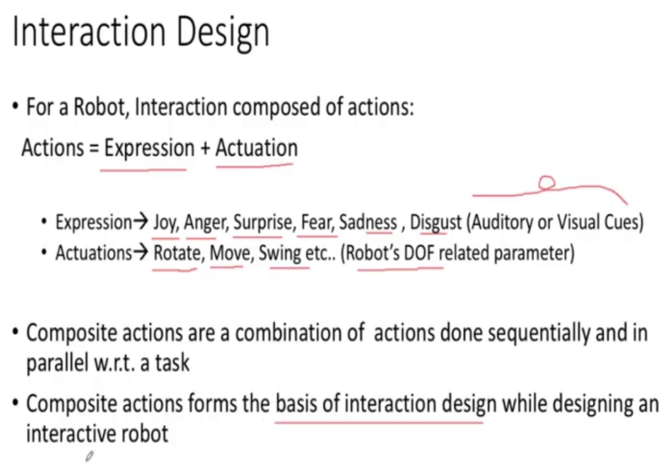

Now, when we talk about interaction what do we actually mean by this word interactions? Well, it is, if the word carries an extensive meaning, but we would be mostly focusing on expression and actuation. When I have initially talked about the smart materials and their you know availability in the robot, in this mechanical actuators we have in mind like rotation, like motion swinging, etcetera related to robots various degrees of freedom.

When we talk about expressions these are emotional inputs like joy, anger, surprise, fear, sadness, disgust, etcetera. This can be given either through auditory or through the visual cues.

Sometimes you can have a composite action like some dancing sequence that robot may carry out with a child and which involves both expression as well as actuation and many times these composite actions may actually form the basis of interaction design while designing an interactive robot.

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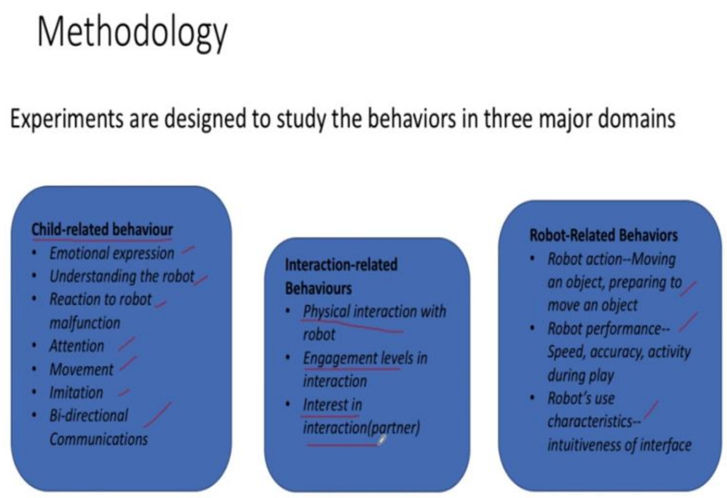

So, the methodology that will adopt towards this direction is; we will note down some of the very important child related parameters, if you have to carry out such experiments; like emotional expression of the child, understanding of the robot, reaction to robot malfunctions particularly, attention, movement, imitation, Bi-directional communications.

On the other hand, from the robots point of view; robot action, robot performance, and robots use characteristics these are very important. From the interaction related behaviours physical interaction is one important thing, engagement levels and interest of the interactive interaction from both the sides. So, these are certain things that we generally try to study in child robot interactions, whenever we carry out such experiments.

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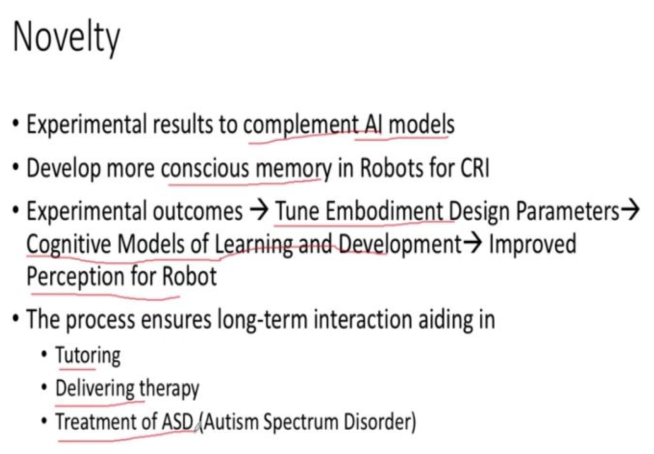

There are various novelties in these experiments for example, these are complement to basically the AI based system. As I have told you that these are embedded intelligence, so these are complement to AI based system and it helps in developing more conscious memory in robots. So, using systems like reinforced learning, etcetera; we can also tune embodiment design parameters through this experiment and we can label of various cognitive models of learning and development and we can improve the perception of the robot.

And in terms of long term interactions tutoring, delivering therapy, or treatment of autisms, spectrum disorder are some of the long term goals that one tries to achieve through this kind of child robot interaction. Now, when we have discussed about the entire paradigm, this is really quite broad in terms of the you know its perspective. So, let us try to see what exactly would be the canvas of this interactions between a child and the robot that we will be trying to address today.

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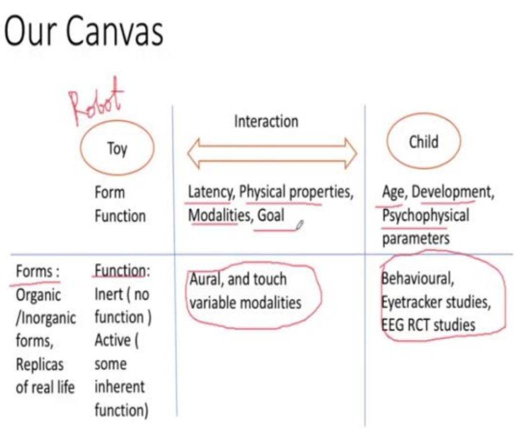

In our canvas, in one side we have the robot which is a sophisticated version of a toy let us say of course, as I told you that for children. For the children it has a different connotation, they do anthropomorphize such a system, but we will talk we will try to figure out about the forms; organic, inorganic, or replicas of real life, functions, inert in level to the functional level, low function to different types of functions.

From the child’s perspective the age of the child, the development, psychophysical parameters, these are the things which will be important for us and this will be studying through experiments related to behavioural studies, eye trackers, and EEG experiments of which, EEG I have already discussed with you.

The interactions can be in terms of oral and touch and variable modalities may be visual of course, and what we will try to figure out are the some of the characteristics in terms of latency, physical properties, modalities goals, etcetera. So, this is the framework in which we will try to work.

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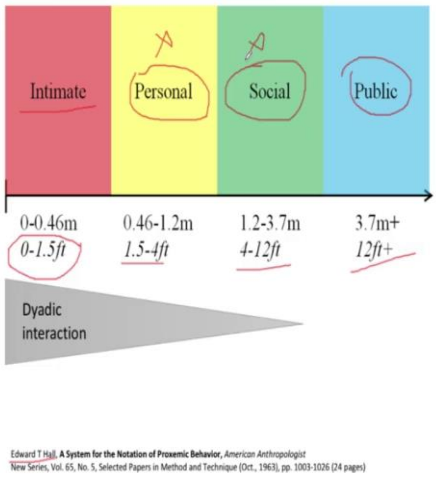

Now, whenever we talk about the interactions, there is an entire gradation of interactions as has been shown. In this particular slide you can see, Edward Hall’s work on a system for the notation of proximity behaviour there are certain distances that one has to keep in mind whenever the context of robot to child or robot to adult interaction takes place.

If it is in the public by that we mean that this must be 12 feet plus distance, if it is just a social interaction then it is generally between 4 to 12 feet, if it is personal interactions with the robot then it is generally 1.5 to 4 feet, but sometimes these dyadic interactions they become very intimate with the kid and in that case it will be between 0 to 1.58.

So, the physical distancing would definitely play an important role and one has to decide that in the very beginning itself. Now, in our experiments, we generally try to keep it at the personal level and some extent at the social level.

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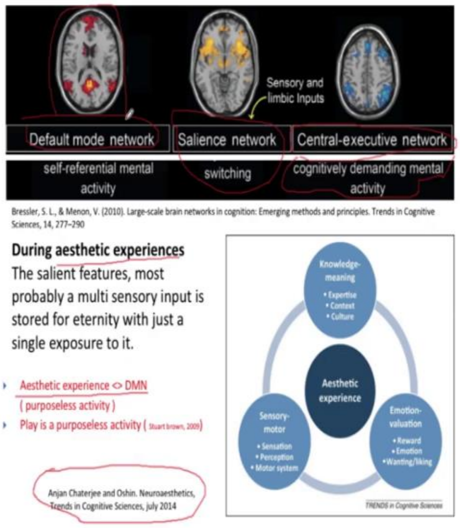

Now, another important thing is that when we consider this entire interaction from a child’s perspective usually, a child will be in a what you call default mode state, default mode network state and at that stage it is a self referential mental activity.

Now, as you bring a robot for interactions, the salience network develops which actually switches the child’s attention and it goes to central executive network and this is cognitively demanding activity. So, that is something that we have to keep, you know you have to keep it with us.

Now, when we talk about the first experiments we will work on actually aesthetic experiments and it is found out in literature like some of these trends in cognitive science. I have given one of the references that aesthetic experiences are somewhat similar to the default mode networks ok, because this is also some kind of a purposeless activity and play also when we talk about play that is also a purposeless activity. So, for play for aesthetic experiences, etcetera we expect that the neural system will be at the default mode network.

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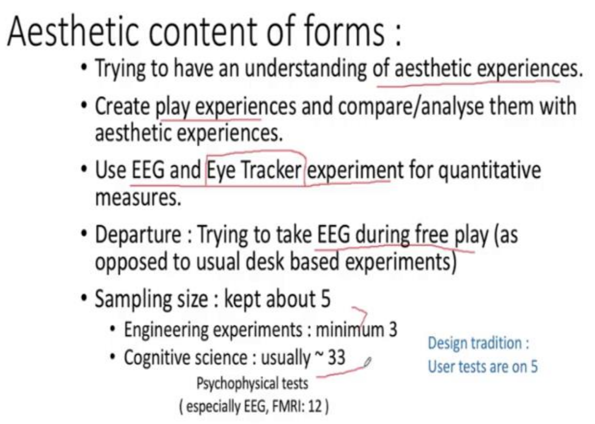

So, keeping this point in mind, because we have to know that from where we expect the sensations to come, the aesthetic content of forms can be designed such that we can try to have you know bring different types of aesthetic experiences. We can create play experiences and compare and analyse them with aesthetic experiences, we can use EEG and eye tracker experiment for this purpose.

EEG, I already told you that it actually measures different you know responses that is happening in the brain with respect to the stimulus. Eye tracker is specially focused on the eye the pupil itself and there are certain parameters which I will discuss soon like fixation time, like the dilatation, pupil dilatation, these are the things that we actually look at in the eye tracker experiment and both of them essentially helps us in terms of knowing whether there is enough attention of the kid towards the robot.

Now, we always try to take EEG during free play instead of putting them enclosed inside an enclosure like for adult age, well that has positive and negative sides. The positive side is that this is most you know kind of a realistic situation, because whenever a child is in free play he is not pretentious.

So, he is you know we are expected to find out the default mode network and the other point is that the flip side is that during the free play the child moves a lot and that actually collapse many times the signal. So, you may not get a good signal and at that time this eye tracker is very useful wherever you lose signal you can at least keep track of the attentions etcetera.

Now, generally for engineering experiments we carry it out with greater than three type of samples statistically, but for cognitive science it is very high it is sometimes ten times higher than that and that is, because the you know there are a lot of subjectivities that comes into picture. So, the tradition is that you should do it as many for as many number of subjects as possible the same experiments before making any meaningful you know conclusion of that.

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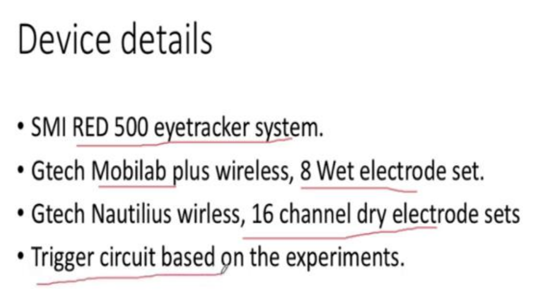

Now, the devices that we use generally in our experiments are SMIs for eye tracker system. So, that is RED 500 that is a pretty standard eye tracker system, then we use Mobilab Gtech wireless, 8 electrode set and also nautilus wireless 16 channel dry electrode set and also trigger circuit based on the experiments.

Now, why trigger circuit is needed is; because we are having two different recording systems EEG and the eye tracker in order to have the same time stamp for both the instruments we need to trigger them at the same time that is why a trigger circuit is very-very important for this kind of experiments.

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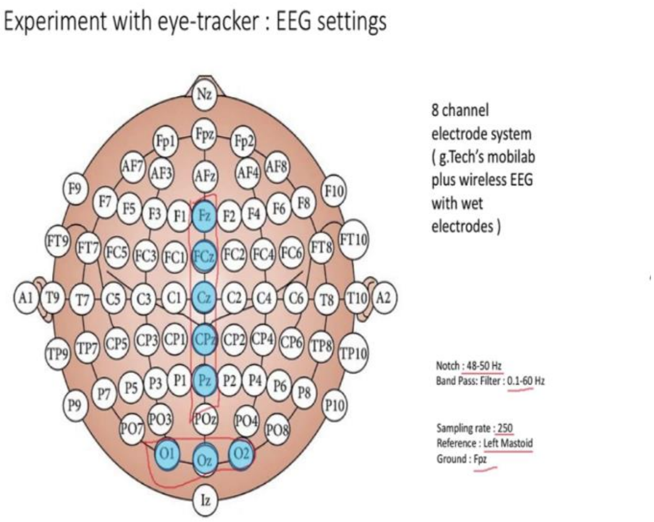

Now, when we will be carrying out experiments with eye tracker with the EEG settings? In this particular case for an 8 channel limitation. I have shown you that what are the regions that we generally choose. We choose the entire you know the central part the and in that the frontal and the parietal part we choose and also, because there are these visual parts there so we choose these occipital parts.

So, there are these 5 points that we definitely try to put and then these three so, these are total 8 channels and these are based on wet electrodes and based on self preferencing, we take a notch filter around 48-50 Hertz that actually takes care of the electrical signals around us, the line frequencies and we also put a band pass filter between 0.1 to 60 Hertz and the sampling rate is about 250 Hz and we take reference from left mastoid and Fpz ground.

So, these are some of the things that one has to keep in mind that what will be our setup, what will be the distribution of electrodes that will be actually carrying out and these are the things that one has to determine. So, in this case these were our choice of the 8 channels.

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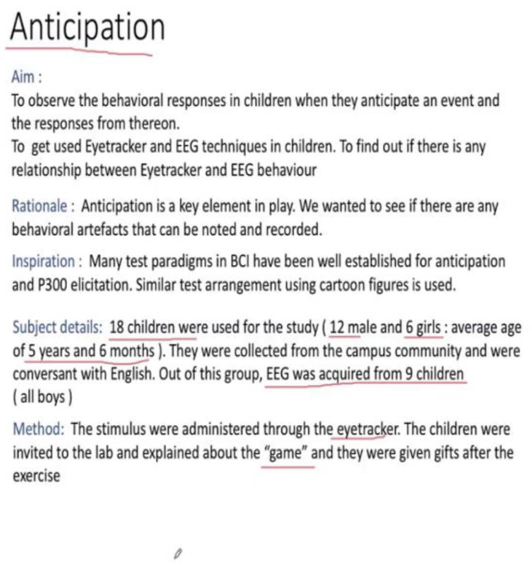

Now, the experiment that we want to carry out is called an experiment of anticipation. So, how a child starts to expect certain things to happen and what if that does not happen in the play? How does it affect his or her behaviour and also how does it bring certain things like ERPs evaporated potentials for example, P 300 type of elicitations. So, that is what we try to find out and in this particular case, we have chosen in this experiment 18 children out of which 12 are male and 6 are girls with an average age between 5 years and 6 months.

So, mostly around 4 to 5 years of age in fact and we have connected it from inside this IIT community, it was and out of this group finally, EEG was acquired from 9 children, because in most of the other cases the EEG signal was point. And of course, the signals were also administered through the eye tracker and the children were invited to the lab and explained about the game and they were given gifts as an incentive. So, this is the way we have carried out the design of the experiment.

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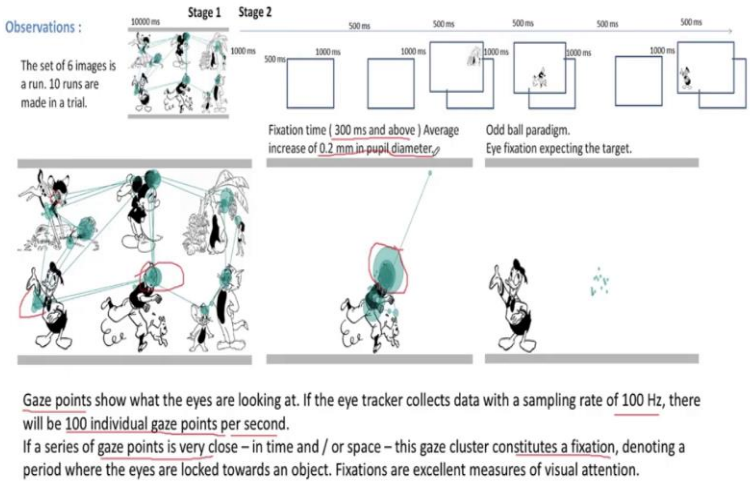

Now, in this particular experiment we have chosen some cartoon characters, because we know that cartoons are very close to a child’s heart. So, we have chosen 6 cartoon characters and we have told them to actually find out one from this 6 which is the most preferred one from the child’s perspective.

And then we start to show these figures many times on the visual screen and tell the child to count that how many number of times this is happening. So, the child will remain you know attentive and there will be always an anticipation that whether my favourite character is appearing or not.

And at the same time we are recording it to the eye tracker about the attention, about the fixation of the child and the EEGs also telling that what is happening to their brain at that particular instant. So, we have chosen these six images and we made 10 runs of them and there was a kind of a 500 millisecond break before the experiment started.

And each one of them there was a 1000 milliseconds between these you know simultaneous characters like 500 milliseconds character to character and continuously changing. We bring an oddball paradigm where the child we you know expects that the character to appear and it does not appear or it appears wrongly. So, that is the oddball paradigm and what we note here is actually the recording from the eye tracker also simultaneously.

Now, for eye tracker there are some important points we have to keep in our mind whenever we are using it, because I have not discussed about this with you earlier, that in the eye tracker it always looks into the gaze points; that means, the points where the child is really looking at.

If you look at it invariably fine wherever there are some actions happening or the eyes, etcetera these are generally or the head, these are generally very important gaze points. And we, the eye tracker starts to collect the data with a certain kind of a sampling rate let us say if it is 100 Hertz it would mean that 100 individual gaze points per second will be recording.

And if we find that a series of gaze points are very close; it can be in time, it can be in space; that means, the child is focusing on something. So, this gaze cluster will constitute a fixation. Denoting a time period or a space where the child has spent more time, like you can see that there is more fixation on these you know head part of it ok.

So, that is very important that where exactly the child is paying attention to and this fixations time this time of fixation like here you can see that the fixation time is 300 millisecond and above for child. So, this is a measure of his attentiveness his or her and also we measure that how much of pupil diameter is taken place which is in this case the diameter has increased by 0.2 millimetre.

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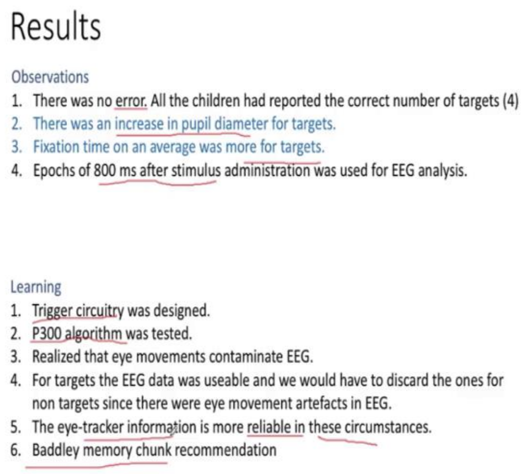

Now, what we found from this experiment is that, there was in none of these final nine cases, there was any error from the child point of view which means he has computed the number of times the figure you know appeared in a very correct manner and there was indeed an increase in pupil diameter for the targets. So, this actually tells that there is an interest that goes towards the target.

Fixation time on an average was actually more for the targets and there was epochs of 800 milliseconds after stimulus administration was used for EEG analysis and we have learned through this exercise about the design of trigger circuitry, the P 300 algorithm itself and that the eye movement can contaminate EEG the realization of that and for targets the EEG data was very-very useful and that actually tells us a lot about the characteristics of the kid and the eye tracker information also you found it to be more reliable in these circumstances.

Now, here what you also notice is that many times while playing this game, the kids will be using something like a memory chunk which is like a baddley type of memory chunk. As you know that in general, the short term memory is only between let us say 5 to 9 items, that is 7 items plus minus 2.

Now, the memory, the short term memory can be increased and baddley proposed that you can increase it in terms of a working memory and that working memory enhancement is what is this memory chunk development and that is something that we found that can happen again and again if we play this game. So, some kinds of expertize gets developed in the child and that actually helps in terms of this memory chunk, you know type of application by the child in a very effective manner.

So, we have noted what experiment, which is related to a sort of practice that you can also try if you have all these experimental units related to EEG characterization of a child. And also related to the study of fixation times, the attention, the area of focus, area of attention, and the corresponding EEG, nature of EEG pattern in the child. So, these are this was the focus in this particular style.

Next we will study a game and this is a game of rhythm. We will try to find out through the game that what kind of a rhythm is most you know attractive to a kid, because accordingly then you can design the cognitive robot. So, let us look into these experiments to find out the rhythm.

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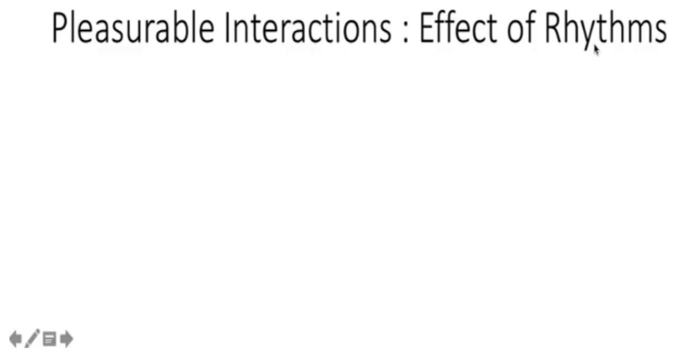

So, we are trying to find out, what are the pleasurable interactions and what is the effect of these rhythms.

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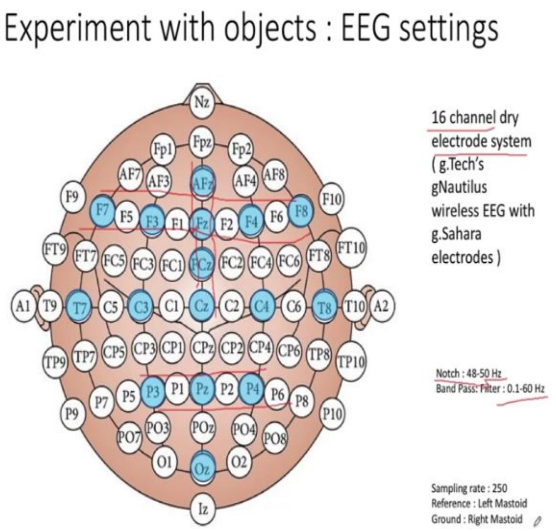

For this case we have chosen more number of EEG setups we have used basically 16 channel, but it is dry electrode system and you have you can see the locations that has been chosen and you already know that how to actually number this. I told you about the EEG experiments. So, that is along the vertical axis and along this axis also you have seen that what are the particular electrodes that we have chosen and both in the frontal as well as in the parietal part and then we have used all this information's in terms of building up the model of the kid.

Now, here also we have used a notch filter at 40 to 50 Hertz and a band pass filter between 0.1 to 60 Hertz, the sampling rate was 250. references left mastoid and the ground was in right mastoid.

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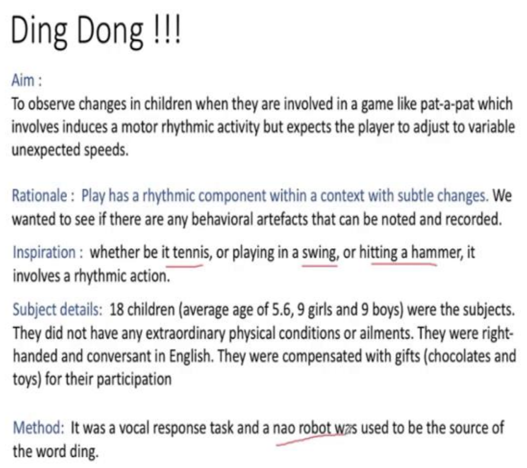

Now, the name of this game we call it as a ding dong game, it is like a pat a pat game, where the robot says something let us say ding and the child has to respond by telling dong. Now, the robot can start to play very slowly this game and then it can tell the child and it can try to increase the speed faster and faster until at a point where the child loses the track robot.

So, we through this interaction as I told you our purpose is to find out what is the best kind of the interval level which is good for the child robot interaction. Our rational for this experiment is that a play has rhythmic components with subtle you know changes. So, we wanted to see whether there are any behavioural artefacts towards this direction and such a thing you can see in tennis, today in case of swings or say some hammer hitting's or you know anything that involves such rhythmic action.

Now, subjects that are chosen here, there are some boys and some girls. So, 9 girls and 9 boys with 18 children is the sort of you know subjects that we have used and the robot that we have used for this study is a nao robot.

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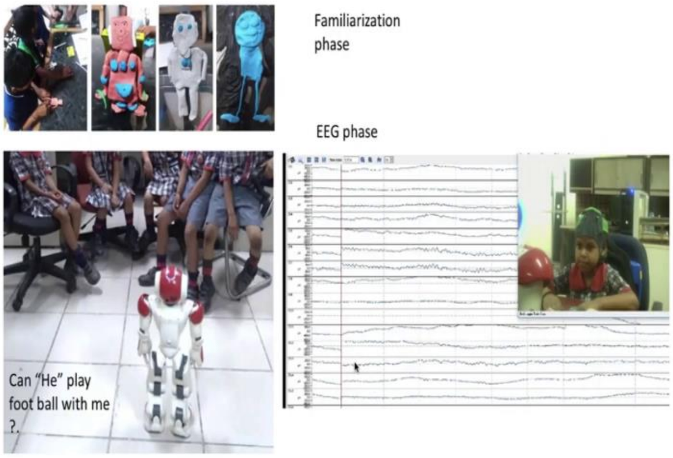

So, let us look into the game first of all we carry out a familiarization phase for the kids so that we can say that you know. So, that we can get the child familiarized with the robot, because many times whenever we bring the kid in contact with the robot she starts to ask questions like can he play certain game with me etcetera.

So, getting familiarized, knowing what it can do or cannot possibly do etcetera is very important and that is the familiarization phase also we record the EEG just to see that whether it is in the DMA, default mode network.

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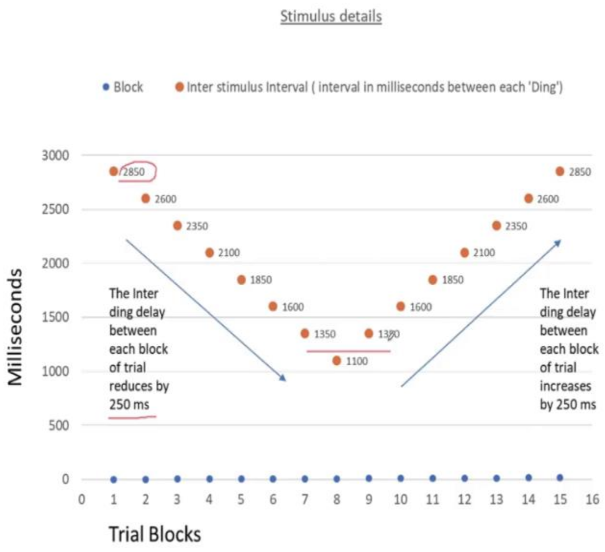

Now, if you look at that at each and every instant we have gradually reduced the stimulus, inter stimulus interval by actually 25 milliseconds. So, starting from 2850 and at every stage reducing it by 250.

We can get the response from the child and we can see here that gradually the child is taking these interactions and the lowest interaction also you can see here in that terms beyond which again the robot increases its speed and interestingly as the robot is increasing its speed. So, the response time also changes for any kid. So, that is very important and the inter stimulus interval the correct design of it is very-very important.

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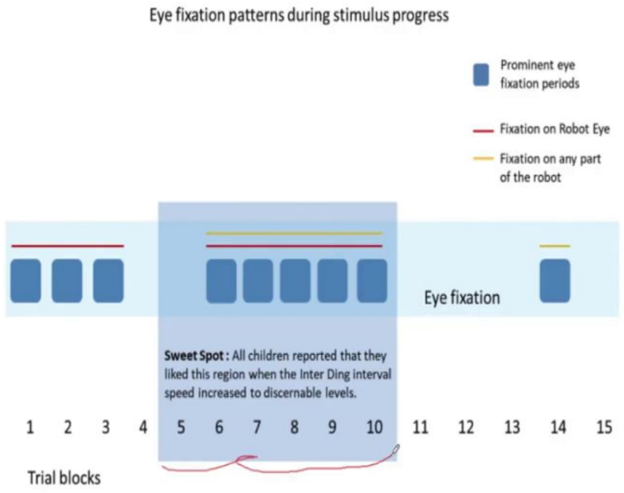

Now, we also put a time stamp and check the eye fixation parameters during these stimulus progress and for prominent eye there is a fixation period and there has to be a fixation of the robot eye and fixation on a human eye kind of system. What we have noticed is that instead of the initial part where it is actually a very slow part of the game.

The game becomes interesting at this high speed level between 5 to 10 to and it is at this level we have seen inevitably at that particular level there is a sweet spot and invariably all the children reported that they liked that particular reason in the play itself. Now, this is where we are showing the response time graphically and what you can see is that before peak the average response time is only about 0.3.

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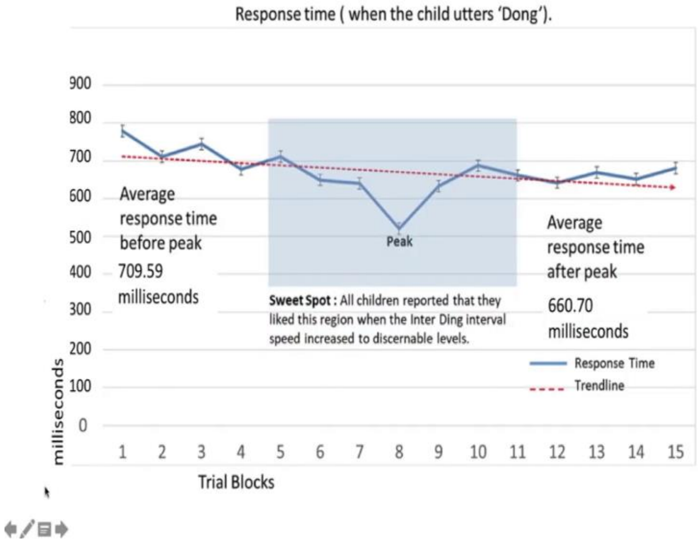

We can see that the average response time before peak is say about 709.59 milliseconds, for the first three trial blocks and after that the sweet spot starts as you can see that it actually comes down to below roughly 500 milliseconds level and then again it increases and the average response time after peak is about 660.70 milliseconds.

So, we can see that after the sweet spot the child gets some kind of a lesson so that the response time of the child improves, it is like 66.70. So, that is something that is important for us.

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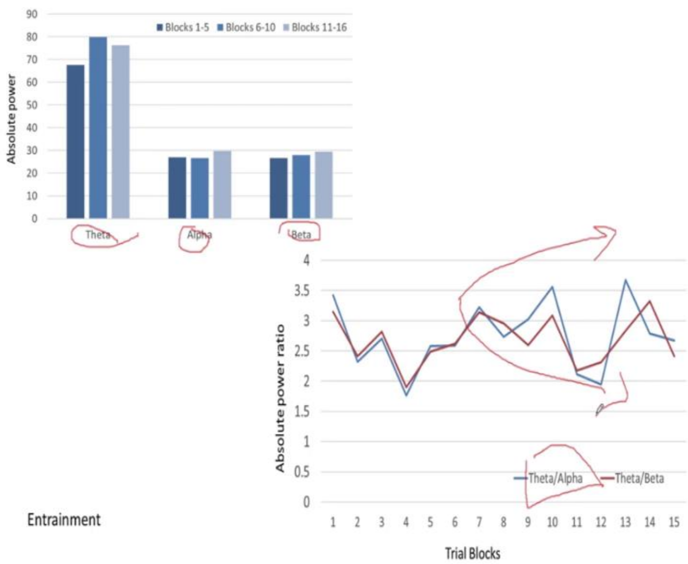

Now, here I am showing these three blocks again and I am mapping here. The three waves separately; that means, the theta wave, alpha wave, and the beta wave. What you can see is that the theta by alpha ratio or the theta by beta ratio both of them show sufficient amount of you know to say that un durations.

But for the block between 9 and 10 the theta by alpha becomes an important point and beyond that you know integrable theta pickup beta type of the thing that actually bring the this particular you know learning into action.

So, we can see that theta alpha is something which gets prominent you can see in this region onwards. So, this according to us indicates the possibility that there is some kind of a learning that has taken place in the child.

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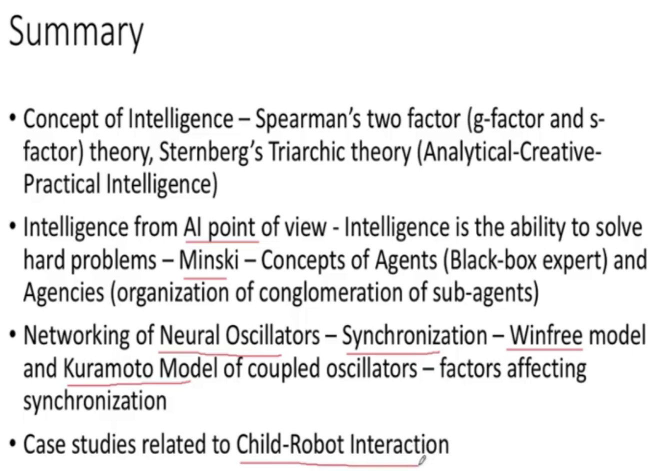

Now, let us summarize what we have learnt in this week. We have talked about initially about the concept of intelligence, where we have talked about Spearman’s two factor that like the g factor and the s factor theory. We have talked about many other theories and we have seen there are opposite theories like Sternberg’s triarchic theory, which talks about analytical creative and practical intelligence and we said that there is no single definition of intelligence you know that can be expected today.

In fact, broadly speaking it is from two perspectives one is from the psychologist point of view and another is from the AI’s point of view and where we have shown some of these intelligence definitions on the AI perspective like Minsky's, where he is talking about this as the ability to solve hard problems. Minsky has also given the concepts of agents which are like black box experts and agencies like organization of conglomeration of sub agents.

We have also seen that whenever these sub agents, developments, etcetera even it is very similar in the brain also it takes place. It involves the networking of neural oscillations, there are issues of synchronizations there which has been modelled by Winfree initially and later on a very famous model, we have discussed about it that is the Kuramoto model for the coupled oscillators that has come out.

And what are the factors that affect the synchronization? Things like say time delay, things like the coupling strength, there are this 80-20 coupling, and things like the synapses, there are different such parameters which actually control the nature of coupling and the possibility of synchronization.

And finally, we have talked about the child robot interactions. So, this was the summary in this four week. Now finally, the introductory lectures are all over, let us summarize the entire you know this introduction of the foundations of cognitive robotics. What we have discussed let us just try to summarize it under certain bullet points.

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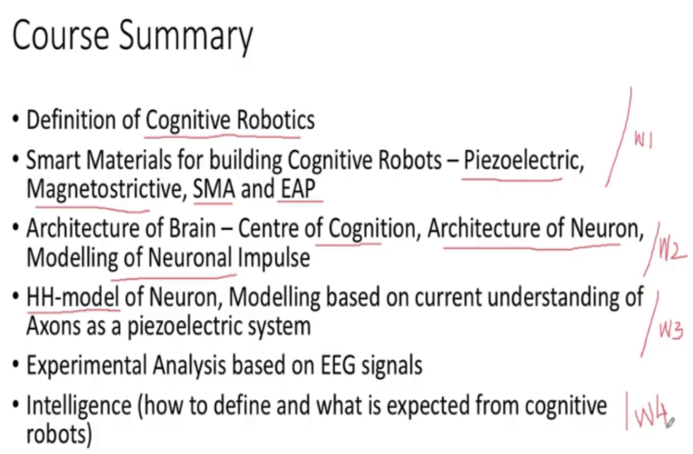

In the very first week, I have talked about the definition of cognitive robotics, if you remember from various perspectives and I have talked about if you remember, the organismoid robots and you know completely organic type and I said that right now, we can be at best at the organismoid robotic space. I have also talked about the building materials for cognitive robots that has the smart materials, different types of piezoelectric, magnetostrictive, shape memory alloy, and electroactive polymers.

So, we first we devoted in terms of defining the cognitive robotics and the building materials for cognitive robotics that was our you know concentration on the first week. When in the second week we have talked about the architecture of the brain, because we said that until and unless you know that how one of the most fascinating living machines the human brain itself you understand it, you will not be able to know that what you have to achieve in terms of the robot.

So, we have discussed about the architecture of the brain, the centre of cognitions, we have also discussed about the architecture of the neurons. So, that was our week two and then while discussing about the architecture of the neuron we have talked about the modelling of the neural impulse and in the next week we started discussing about Huxley Hodgkin model of neuron.

And also we have said how you can further expand that model in terms of our current understandings particularly, in terms of the action that you can model it as a piezoelectric system and also I have talked about various types of experiments that you can do using EEGs. So, a little bit of introduction to EEG signals I have given you.

Finally, in the last week we have talked about the intelligence. How to define intelligence and what is expected from cognitive robotics along with a few very preliminary experiments that we have carried out. So, that is our final journey in this week. So, let us hope that all these things together will give us a kind of a platform, based on which we can do the advanced studies on cognitive robotics.

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Now, I must acknowledge for this particular lecture my students Aravind Sanmugam and Anirudha Bhattacharjee for their research which I have presented through this one.

Thank you.