Learning about Learning a Course on Neurobiology of Learning and Memory

Prof. Balaji Jayaprakash
Centre of Neuroscience
Indian Institute of Science, Bangalore

Lecture – 10
Limitations of the Model: Latest Inhibition, Elemental Vs Configural, Learning Theories

Hello and welcome to the lecture 10 of Learning about Learning a Lecture series. And in so far, we have been seeing about, we have been learning about Rescorla Wagner model for explaining how associative strength develops in an animal when we are presenting two stimuli, stimuli 1 we call this conditional stimuli CS along with US, all right.

So, we went ahead and said there are basic assumptions in this model and if you list out those assumptions and write down a very simple mathematical encapsulation of those assumptions in terms of a difference equation we saw how such an equation can explain very very very non-intuitive behavior that we have non-intuitive experimental observations that people have seen so far as the Rescorla and Wagner's model was proposed.

These are starting from one Rescorla's own experiment by involving multiple presentations of US, where the number of presentations of the US is higher and despite that presentation the animal fails to learn the reason being that the US's were presented in an non-contingent manner in a purely random manner, right. Compared to a control group where always the US and the CS were presented in a contingent manner. Number 2, is the experiment from Garcia and Koelling where we saw that you can have different kinds of CS is pairing with different USS in such a compound presentation, different stimuli have different tendencity propensity to associate with the US.

For example, in this specific example Garcia and Koelling showed flavor tend to be associated favorably with stomach malleus versus tone and light. On the other hand in the same experiment instead of US being a stomach malleus if you were to use an electric shock we saw that tone and light would preferentially associate with the electric shock.

Here even though both the CS all the CSs and USs of represent together the association seen to develop preferentially for one set of CS and the US rather than the other. And

then third intriguing of observation was the fact that if you were to pre-train CS and then present it or follow it by a compound presentation where the pre-trained CS along with the new CS is presented with the US, then the pre-trained CS completely prohibits or inhibits the development of an association for the new CS.

In this specific example of illustrated by Kamin, what he did was he used he pre-trained the animals within tone and shock then he followed it up with the presentation of a compound stimuli involving tone, light and shock. What he later found out is that if you test for the tone the animals do remember the association they develop an association very clearly for the shock, tone in the shock. However, the light and the shock did not develop any association; the comparison or the control group here would be just the light and the shock.

So, these observations together with some of these as assumptions made by Rescorla we saw how we can explain this beautifully using this mathematical model. In a nutshell the contingency aspect of the associative behavior is captured by two of the fundamental associations in the Rescorla number one there is a set V max. There is a maximum amount of learning for a given US. Together with that the learning per say is determined by a surprised element which is calculated as a difference between the present response and the expected maximal response, right.

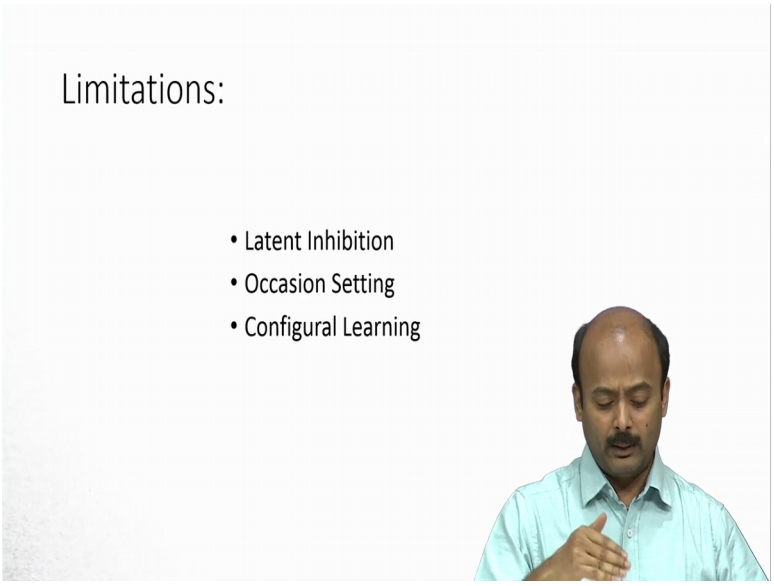
When you are when you are calculating the present response we are adding up all the responses of the stimuli that, this behavior that summation of all the CS responses together with the fact that there is a maximal response, gives or captures the phenomena in which the contingent CS or contingent CSs alone are getting associated while the non contingent ones do not. While the differential associate ability is captured by the alpha the learning rate coefficient alpha which we have been using in our model.

Now, such a simple model as a choice is wonderful and explaining so many different observations just these are only a few of them that I have listed. So, many different observations and in fact, we said it makes wonderful predictions that are not foreseen before such as over expectation and we saw how it can explain over, Rescorla and Wagner can explain over expectation and why it is not non-trivial to, why it is non-trivial to be able to come up with such kind of expectations. Despite all such wonderful things every aspect every model it has its own limitations. The mostly the limitation stems from

the fact that we are applying or this model is applied to brain that is naïve, that is does not have any prior experience, right. So, if the prior experience is not taken into account here at all and that shows up in multiple different aspects.

One of them, I am going to list out few of them and then we will see each one of them when described a little bit here each of these limitations. The idea here is to not comprehensively discuss all the limitations, but I am hoping that just with the framework we are illustrating few of these examples of the limitations whereby you will be able to take this forward in your own case wherever you are seeing, wherever you are using these learning models to apply into our own situation by extending some of these examples, all right. These examples in my opinion covers the basic limitations of the Rescorla Wagner model.

(Refer Slide Time: 07:56)



So, what are these limitations? Number 1, latent inhibition it is a phenomena in which the animal fails or animal finds it harder to associate or ignores to associate a given stimuli, which normally it would have associated but because of this phenomena it fails to associate. Like say for example, in our general case of CS and the US normally you would have written CS plus and US develops an association. But in this case as we will be seeing it in detail little later the CS if under certain conditions fails to develop an association ok.

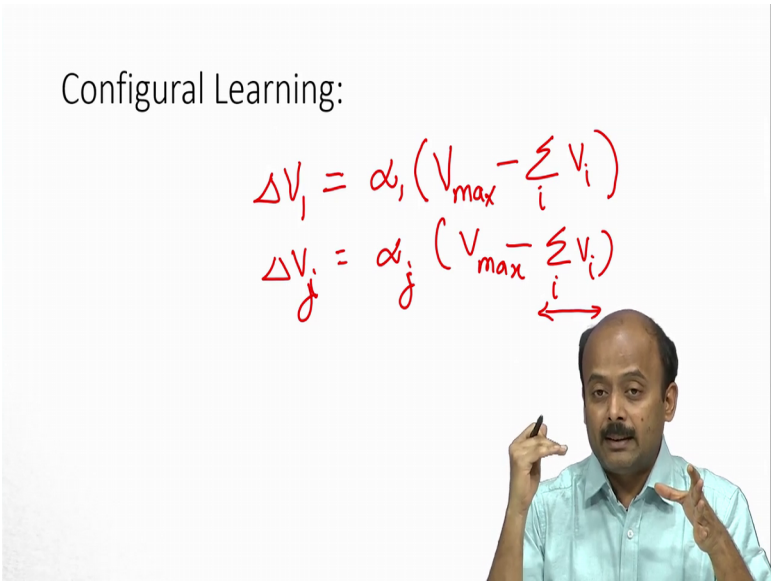
And these conditions that inhibits or prevents the CS to develop an association we call that as latent inhibition that because its it is preventing the CS to form an association ok. It is also known by a different name CS pre-exposure effect and but I am going to stick to the notion of latent inhibition, even though there are I will bring out subtle differences though they are very important differences in this what this name or the connotation of this terminologies are ok. Latent inhibition or CS pre-exposure effect.

Followed by an experiment by Rescorla himself on something he termed US occasion sitting. Again, while we describe this experiment and then its observations, so we will see there is no simple way to capture directly and just sticking to what Rescorla and Wagner has stated to explain how such a phenomena can occur ok.

This is a again an example of modulating the CS, the meaning of the CS, how that can actually differ, that can either facilitate or not form an association. Here we will be describing exact experiment done by the Rescorla himself. And then one important the last, but not the very not the least an important aspect or assumption of Rescorla and Wagner is about elemental learning and as opposed to elemental learning we will be talking about a configural learning, what this configural learning means and how the model fails to explain how an association can develop or not develop in such a setting, ok.

We will do it one by one each of these experiments. And let US start with the configural learning itself.

(Refer Slide Time: 11:11)



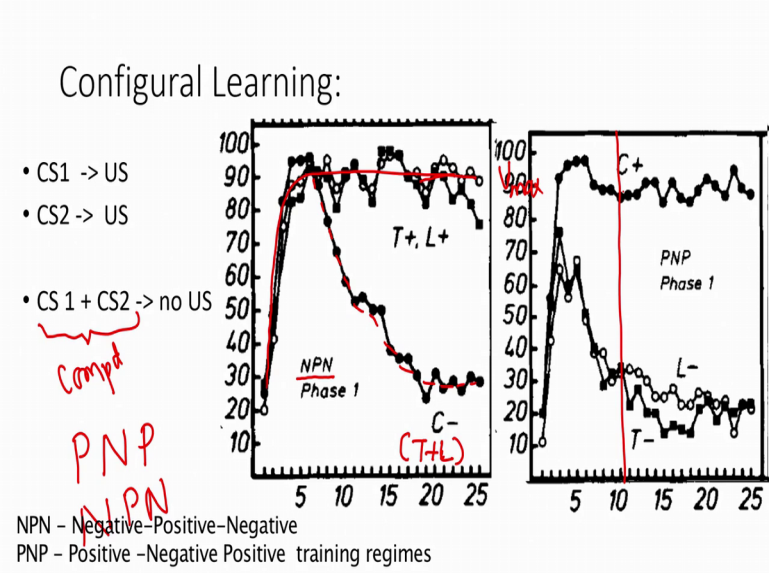
This case stems from the fact, Rescorla and Wagner's if you remember, Rescorla and Wagner's equation for multiple stimuli if you want to estimate then the way you will do that is that hey that is very simple. What you do is you break up this compound stimuli in to each one elemental stimuli.

And then I am going to write down an expression or the change in response for each of this stimuli and then I will just add them up and that is that will give me the response that I can expect in an compound stimuli. That is, he states in a compound stimuli the change in response delta V of stimulus 1 is given by alpha we are here assuming alpha to be the same, but you can explicitly write alpha; if you assume it to be same then it is no subscript needed. But if you are specifically taking into account each alphas for a different stimuli are associatable in different to different degree then alphas need to have a subscript V max minus summation over all the responses of the CS alone, CS until that point in time. Now, that is the assumption here.

We could, so number 1, we could write down this change in response a as individual such things, right. In general delta vi equals alpha I V max or let US say since I am going to use the i here alpha j minus V i. Now, that assumption comes under question in this experiment. The assumption number 1, we can predict the response at that point in time by simply adding all the responses and then the resulting learning for each of the components can be spitted to the, I mean that is both of them are essentially the same in

terms of you are saying that you had some at some level the responses can be linearly summated right. So, that assumption comes under question here.

(Refer Slide Time: 13:58)



How? Where you take a CS let US say CS 1, you pair it with the US, all right and then you also take CS 2 you pair it with the US. However, you do something else in here which is when you do a compound CS 1 plus CS 2 there is no US. This kind of training in general is called as a discriminatory training.

And the CSs that are paired with the US, you name them as these CSs you call them as CS plus indicating that they are paired with the US and these any CS in this case only one, but presented together so we call this as a compound right a compound stimuli but the compound stimuli predicts no shock, right. So, these are called as CS minus ok.

In this special case what we will, we want to illustrate a difference between individual stimuli and the compound stimuli. So, in the experiment that I am going to describe what people have done is that they have taken tone alone pad with water and light alone pad with water, tone plus light no water ok.

Now, what we are going to see is that how its done in both rats and rabbits I believe and its the reference we will get towards the end of the lecture here. But the point here is they are going to follow the animals response to the water intake ok. So, if you were to measure the CS 1 plus water you would expect that as a function of number of trials, you

will see that there is a gradual increase and then the animal will learn that they will learn to take in more and more water and it will saturate around V max, no surprise that. However, what is in what is interesting is that if you were to present them all together that is you can take the CS 1. So, what they would do is they would call this as positive contingency you are giving water, right. So, it is positive contingency.

They have presented it in two different kind of manners, one they call it as PNP presentation, positive contingency followed by a negative contingency at followed by a positive contingency. That is CS 1 US, CS 1 plus CS 2 no US, CS 2 alone US, that is PNP presentation. They also do it in a different presentation which is NPN presentation just to be consistent, right. The idea here is can the animal learn here when you are presenting both the CS 1 and CS 2, it is the it is not going to get the water but CS 1 alone and CS 2 alone it will get the water.

See in the Rescorla's model that is not something that you would expected because you would see CS 1 have acquired a value, some value we would have call it as V 1 as a function of number of trials and CS 2 V 2 as a function of number trials it would have occurred some value. And then when you are putting into a compound trial when we are calculating how much the change in response for the CS 1, we would have added up the response for the CS 1 and CS 2 and see what is the difference proportional to the difference I would have just added it. There is no way I could introduce the fact these two same stimuli presented together and not giving a response the V max changes, no, that does not happen.

So, you would predict in a compound stimuli always the response of the individual animal would be summation of these two. But what did they see? What they are seeing is that in the y axis what they are measuring is the number of responses water intake responses and normalized to the maximum, so you are looking at about the percentage responses here.

So, you can see the tone alone, they calling it as tone plus which is the CS plus we talked about. Light alone again light plus the CS plus we talked about. Both of them go up nicely and beautifully and saturate right that is your V max individual V max for this experiment. However, in the compound which is this which they calling it as C which is essentially T plus L when they are training it such that T plus L would indicate no water

response. Initially they are following it they are going up, but in no instance of time you will see the response of the animal to the compound is higher than the sum of the two. It is not even higher than one of them, its definitely not the sum of the two.

And in fact, if you train them enough what you see is in the other behavior which is they learned to not respond this is exact opposite of what they have learned with just the individual responses. Now, just to show that this is nothing to do with the order in which they have trained, that I have here shown the training paradigm where they have presented it in NPN manner, that is negative, that is compound stimuli here first followed by a positive which is either the tone or the light one of them, the next set of things will alter and then a negative ok. You can also do it the other way round and it is not any different ok.

The compound stimuli is predicting a reward here with predicting a water here, while the predicting is meaner is paired with a water US. However, that tone alone and the light alone does not predict water. So, again the animal learns to discriminate these two stimuli very beautifully ok.

The trouble is if you want to explain with Rescorla and Wagner, at any point in time when you are taking like say for example, this cross section when you ask me what is the response, there is no way to say hey is it a compound stimuli or compound presentation or an individual presentation, right. It is as if the animal when the tone and the light is presented together, the animal decides to encode decides to view this togetherness together of the light and the tone as something completely different than a simple presentation of tone and the light.

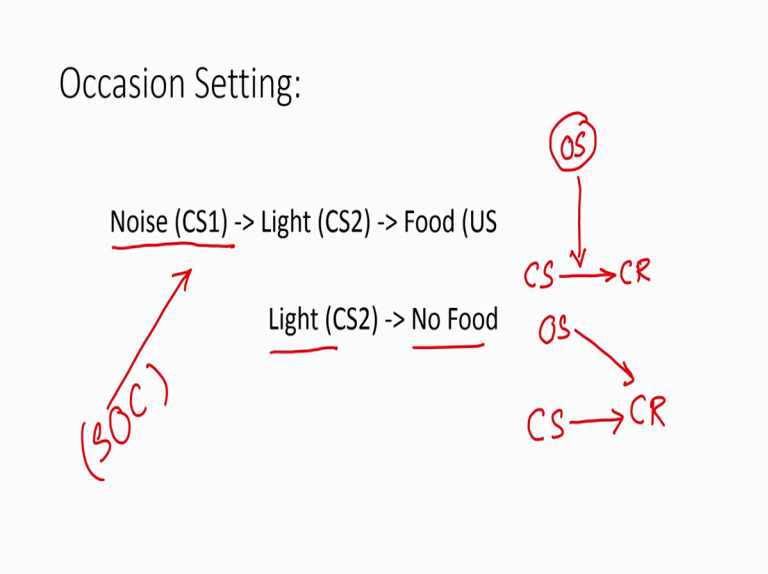
So, they called it the tone and the light gives a new configuration, it is not as if that a simple elemental addition it is a new configuration a new compound, it has a new meaning to the animal. And such kind of meanings are hard to attribute with Rescorla and Wagner directly of course, you can extend it and you do the corrections and implement it, but the point is just by itself we may not be able to explain them, all right. So, that is about the configural learning, learning part.

And now this slide summarizes, depending on how you trying them the stimuli individual stimuli may or may not be treated as individual stimuli when we are presented in a compound. In this through this discrimination training these people were able to

show that you can at the animal does treat these compound stimuli as a different configuration rather than a simple addition of two stimuli presented together. So, that is for configure a learning.

Next in our list is the experiments on occasion sitting.

(Refer Slide Time: 23:13)



These are experiments done by Rescorla himself. Wherein, he took these are the animals and then he is asked instead of just pairing light and food light and food alone like CS and the US alone what I am going to do is, I am going to use another stimuli, another signal. CS 1 followed by light, followed by the food versus light no food. Again discrimination training; so what we are doing here is we are trying to teach the animal it is not just simple light means food, but light means food only when it is preceded by the noise. Again, that notion of something preceding a CS and how do you capture that is not set in that model at all.

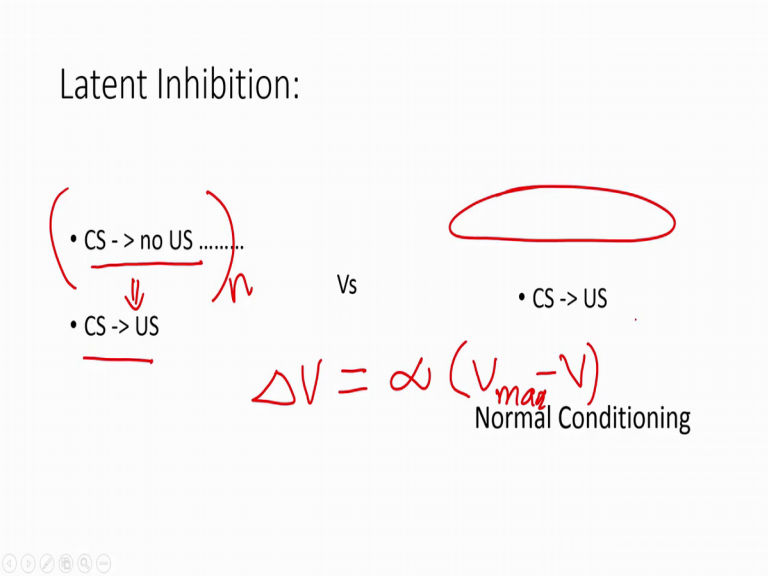
So, what you see is that the animal again beautifully learns to discriminate this, such that only and only when the light is preceded by the noise, the animal starts to pick for the port, while the light appears all by itself that is the animal does not pick for the food. So, how do we account for that? So, there are two possible explanations Rescorla put forward, one being the fact that hey look there is the CR, now you can think of the CS eliciting a CR association being formed.

On the other hand this CS eliciting a CR response could be modulated by the noise in here the CS 1, he call it as an occasion setter that is he said when there is a signal that is proceeding a CS then that signal acts like an occasion setter wherein the animal says now this light means something. So, this occasion setter modulates the associative strengths or the expressibility of the CS CR association, number 1.

Other equally possible explanation is CS eliciting response no big deal and occasion setter by itself is also eliciting a response ok. It is a directly acting on the suppression of this response or presence I mean our amplification of this response. So, there are subtle differences between these two theories we will not go deep into that, but it is just to mention that there are multiple ways one can actually go about explaining what role such occasions setter place here. In more recent view that our laboratory takes it is the neither of them or maybe a mix of these two, what we would like to put forward is that these CS 1s we would call this association is because of a higher order conditioning in particularly in this case we call them as second order conditioning.

Again, we will probably towards the end of the course talk a little bit about this higher order conditioning. So, let US hold our forces till that point, but here what I want to drive across is that multiple ways one can I go ahead and explain, but all of them are outside the purview of the Rescorla and Wagner, nothing within the Rescorla and Wagner which you can use to explain such a behavior. The behavior wherein a stimuli modulates the associatability of another stimuli to with the US, good that is for occasion setting.

(Refer Slide Time: 27:21)



And then, let US now look at the third and the final limitation that I told you about which is latent inhibition. See this is this terms from our common experience right. So, we tend to ignore things that happen routinely in our life, right.

So, if you ride in a car to our office and then you tend to park in a place, right in a parking lot. If there is a small change a subtle change in the location that you are parking are there is a overall structure to a parking lot, it is a highly likely you may not see or notice such a change. On the other hand if there is anything drastic that happens it requires much more a drastic change for you to actually pick up that model that change to capture your attention.

So, animals are not any different we are also animals. So, they do the same thing and then you can actually test this in the laboratory setting too. How do you do that? So, what they did was that if you have a series of presentation not just one or two a series of presentations of CS no US, CS no US, CS no US all right. A continuous series of presentations of CS and no US versus no such pre-exposure at all, no such exposure to the CS.

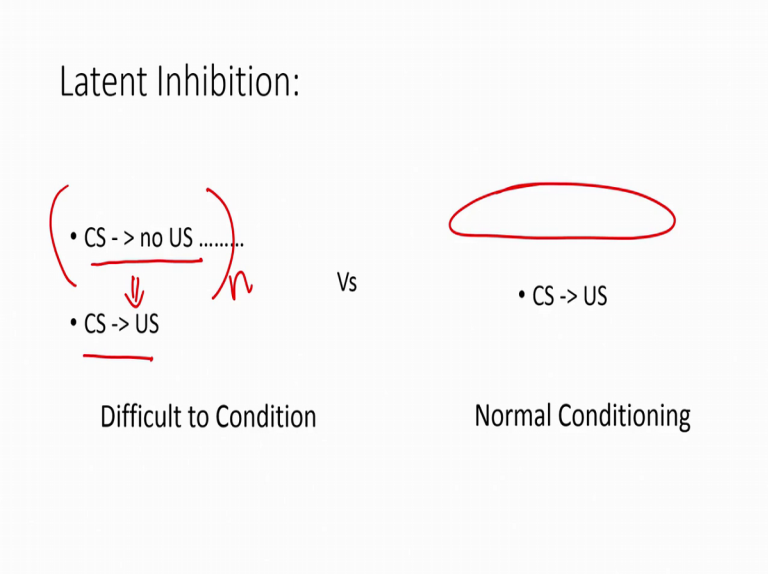
Now, let US take two of these groups. The idea is that we are going to compare their associatability that is group number 1 CS and no US multiples multiple number of times. So, let US put that as present in n number of times we are presented, followed by CS US

association. Let US compare them with no such no such presentation no such pre-exposure, but directly take these animals and then give them CS US association.

Again there is no way to incorporate how the value of this CS and no US inside that difference equation that we talked about, because for all that matters to US in the framework of a Rescorla and Wagner all we would do is delta V equals alpha times V max minus since its one stimuli we just say V at that point in time. Now, during this pre-exposure right there is no US and it is just a simple that V max is equal to 0 and the animal does not assimilate anything at all there is no way I mean it is it starts with 0 and remains, there is no way you can incorporate that change that idea that this has been exposed multiple number of times.

Now, that does it matter? It turns out it matters a lot. When you do this to this animal and then take the animal and then train them in CS US versus no such pre-exposure and then train them in CS US.

(Refer Slide Time: 30:48)

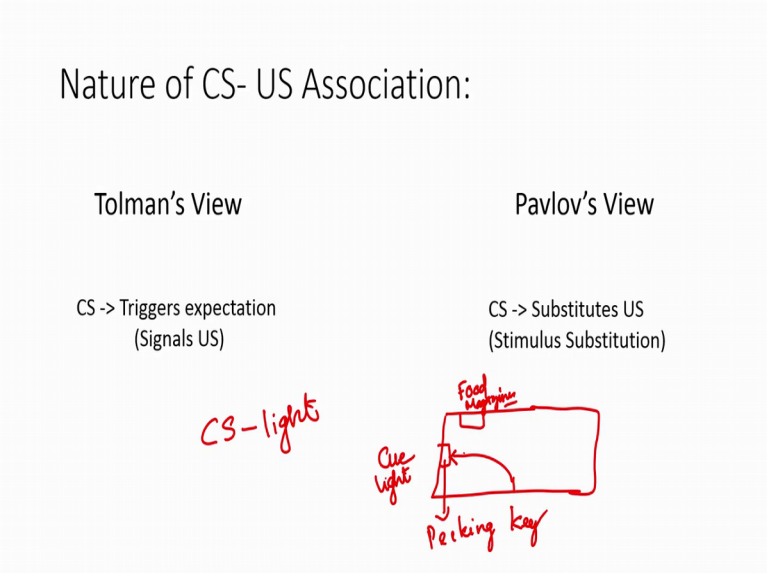


What do we see? Here we see a normal conditioning no problem at all this is exactly what you predict as you predict by predicted by Rescorla and Wagner. However, what you see here is the this group of animals are extremely difficult to condition, they do not their associativity somehow is modulator or is reduced by the repeated exposures of CS, no US exposures. See the associate ability in Rescorla and Wagner is a function of CS

and the US alone nothing else. There is no notion of pre-exposure there and as a result you that is a constant.

So, it does not capture the notion of this pre-exposure effect people also call it as latent inhibition that is these exposures inhibits the ability of the this particular CS, the pre-expose CS to associate with the US. With that kind of completes our discussions on the limitations of the Rescorla and Wagner equation, but I promised you in the last lecture that we will talk about this limitations and then come back and then see what come back and ask what exactly is happening in our brain when we are learning these associations ok. We will do a little prelude to this discussion and then we will continue in the next lecture, but then the prelude is as follows.

(Refer Slide Time: 32:33)



We are going to talk about the nature of the CS and the US association. There are two different views here, view number 1 which is the normal or the regular view you would have predicted which is that, when you are actually making the animal to form an association between the CS and the US, the CS triggers an expectation of an arrival of the US or so to speak it signals the arrival of the US as a result you are eliciting a response, right. So, that is the Tolman's view.

If you actually think extrapolate a little bit I would say it is a little bit of a cognitive view that is the animal knows that the CS is going to I mean consciously here I am talking about, knows that the CS is going to predict the US as a result it prepares for it there and

the response is the effect of that right it is an it that is the notion of expectation. The CS triggers an expectation, triggers an understanding I mean develops an animal develops an understanding such that the CS slowly, but steadily develops and expectation within itself, hey look I am going next time when I am doing this when I am hearing this, I am going to have this.

So, that in a Pavlov's dog example we would say slowly the bell develops an expectation into the animals head, hey look the bell that we heard right now I am that I heard right now is going to predict the food for me. And in response to that expectation the animal develops the habit of salivation ok. That is the Tolman's view. Versus, Pavlov's view is very very very different where he says the animal does not necessarily need to think about the a CS, in terms of expectation in terms of what it is going to predict but in it is kind of developing and involuntary, right. It is not conscious it is not a cognitive process, but it is a more a reflexive development, wherein he says the CS literally substitutes the US thereby the response elicited by the US that you are is elicited by the CS 2.

Now, that is the view that he initially developed, but the later extensions you can actually mean clearly, that view had its major flaws because as I was indicating to you in the during the description of Pavlov's dog's experiment the CR and the UR need not be the same. And if that is not the same, but directly that falls apart because the CS can elicit different kind of responses, CS and I mean CR and the UR can be different.

But you can take a little bigger picture view and still in lines with Pavlov, where you can say, hey look the there is an association that develops between the CS and the CR, but the animal does not necessarily think or make an expectation or develops an expectation with respect to the CS, but its more reflexive. The animal really thinks the CS is the US. Now, how do we tell apart which is which.

This was very nicely delineated you know experiment by Jenkins and coworkers, wherein they made use of pigeons picking behavior characteristics. Pigeons when trying to peck for food all right, depending on the nature of the food they have a differential picking behavior. If the food happens to be a solid palate then they would pick with open beak and closed eyes. The reason being oh the food particles you need for the solid food particles you need to be able to swallow it, small particles you need to be able to swallow it, so it you need to pick it with wide open beak. But then when you are picking that can

spurt out some of the powders which you do not want to come into our eye. So, you want to close it. So, that is reasonable.

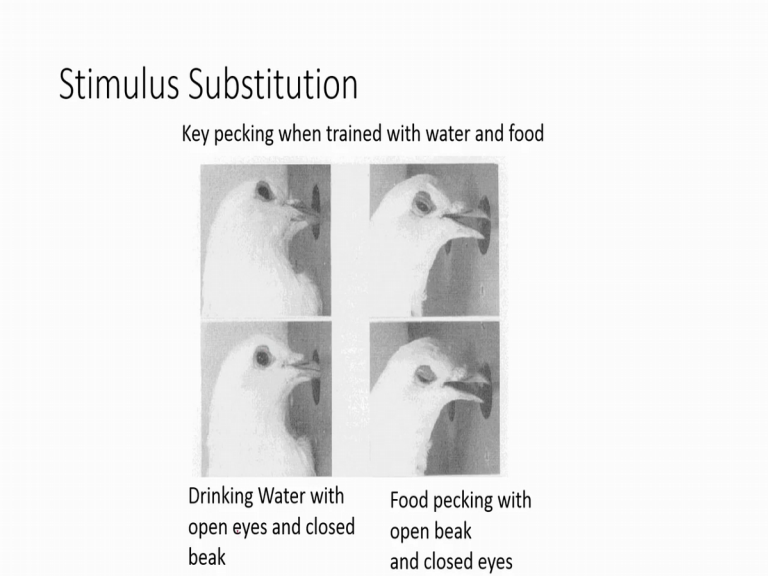
However, when you train the animals train these pigeons with water reward or a liquid food then they tend to pick with closed beak. Again, common sense because they cannot drink the liquid food with open beak, they need to have a closed beak so that they can sip it in. And since it is not going to spit around to your eye there is no powder that is going to come out of it because it is just it is a liquid. There is no point closing your eyes you want to keep it a wide open so that you can be aware of the surroundings and be alert to the predators. So, in short pigeons have this behavior wherein solid food they pick with open beak and closed eye, liquid food they would go with closed beak and open eyes.

Now, what they asked, what Jenkins and coworkers asked is that if the animals were to actually follow the stimulus substitution idea of Pavlov then I can make use of this characteristic differential characteristic of the food picking, and then try to see is it really happening and how they pick not the food, but the queue itself. So, what they are going to do is that, they are going to take these pigeons and then train them train them in a behavior where there is a queue, a queue light appearing lighting up and in response to that the animal has to go and pick this queue ok, there is a light queue ok. They have to pick and then in response to their picking you will have the food that is been delivered in the magazine, right.

Now, you can have it in two different ways, one for a solid food you can deliver it to a magazine so that for every light queue you have the food, so that is very simple. So, if the CS were to be CSs all the time a light queue and the animal has to pick key, this is called a picking light queue and then let US call this is a picking key. In response to their picking either they will have the solid food delivered or a liquid drop that they can go ahead and sip it in.

So, now, if they were to have the similar substitution then they are picking behavior should be very different that is when they are trying with the solid food you would expect them to pick if pick the key, because they are thinking that the stimulus I mean the CS is itself the US they would pick as if the key is a solid. While on the other hand if they are trained with liquid food they would pick the key as if it is a liquid.

(Refer Slide Time: 40:42)



And what do we see? They captured with a very high frame rate cameras and what they see is exactly that. As you can see when they are trying when the pigeons drink the water here with open eyes and closed beak, they are trained with water reward on the other hand with the open beak and closed eyes when they are trying with a solid key, food.

With that I would like to conclude this lecture and then see you in the next lecture.

Thank you.