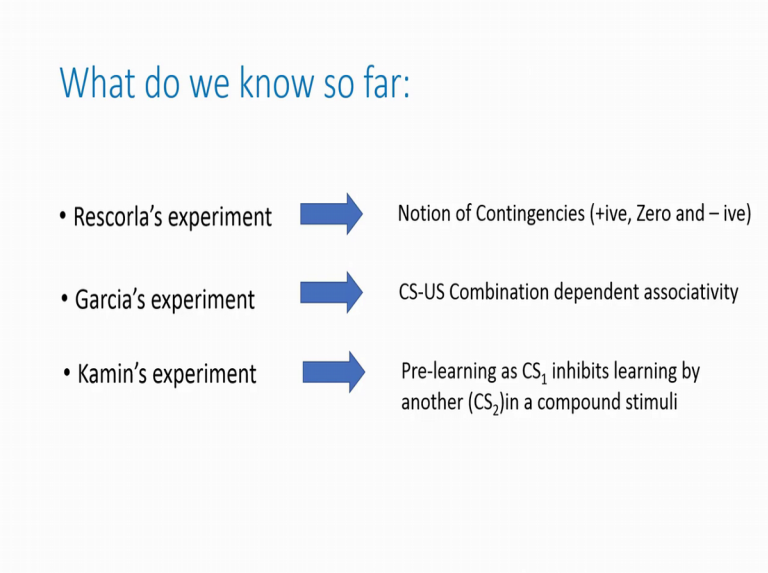
Learning about Learning: A Course on Neurobiology of Learning and Memory
Prof. Balaji Jayaprakash
Centre for Neuroscience
Indian Institutes of Science, Bangalore

Lecture – 05
Introduction to the Rescorla Wagner Model

Hello and welcome to the lecture 5 of the Learning about learning Lecture series and in this lecture we are going to develop a model for an associative learning, as I was alluding to it towards the end of the 4th lecture. So, the idea here is that we are going to develop a model, the model will explain some of the observations that we have seen so, far in through experiments where that that I have described. So, what do we have in terms of the model.

(Refer Slide Time: 01:03)



In terms of the model what we have is number 1 from Rescorla's experiment in from Rescorla's experiment, we know that there is a notion of contingency right, the idea of contingency. Here what you are trying to say is that its only the stimuli right, we have all the while, we are trying to study about how two different stimuli are getting related to I mean how the animal learns to establish a relation between two different stimuli.

And in response to that how it modifies its behavior right that is all we are trying to learn here and from Rescorla's experiment what we get out from the Rescorla's experiment is this notion of contingency alright. We talked about positive zero and negative

contingency, any model that we try to develop should be able to account this should, be able to explain this experiment and its result very naively and naturally remember.

Number 2 we talked about Garcia and Koelling's experiment alright, what is that that experiment tells you not any two stimuli right it is not just any two arbitrary stimuli that I can take and then try to make an association. Or, in other words the nature of the stimuli matters and it is this nature that determines a given us combination to be more susceptible performing an associative connection are less associative strength for this connection.

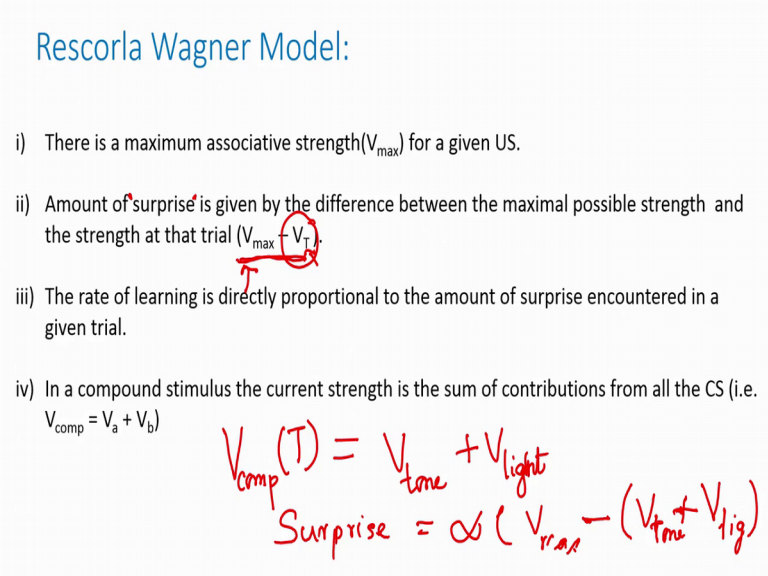
So, this is an example where we have trained, where we have saw Garcia had trained the rats in flavored and bright noisy water and then the rats tend to associate more with the flavored water, when there is stomach malleus as opposed to bright noisy water right. That has been observed in this experiment right. So, you given US CS combination defines the strength of association ok, that needs to come out naturally to in this model. Third is this wonderful experiment by Kamin where he said pre learning a given CS can actually inhibit learning in a different setting when you are giving a compound stimuli.

So, let us say if you have learned the CS 1 and then you are present put into another situation, where you are presented both the CS 1 and US CS 2 and asked to associate with the same US. Then the CS 1 and inhibit the formation are the learn formation of association are the learning of CS to US association, in more specifically in this example we talked about how tone and light, when presented together along with the shock can acquire associations of the tone shock light shocked very beautifully. However, if you were to take the animal and then train them pre train them with tone shock or light shock for that matter.

Then you present them with the tone and shock together with the I mean tone and light together with the shock, then light and shock does not form an association. This is what I call it as pre learning of 1 CS can inhibit the learning of another CS US association when presented in a compound manner ok. So, there are many other such experiments.

But these are some of the salient features that we are looking for in our model and our model should be able to nicely and continue smoothly explain all these observations ok. Good now what did the model say, let us recap what it says number 1 it says.

(Refer Slide Time: 05:13)



There is a maximum associative strength for a given US. So, let us call this associative strength as V or since its maximum let us call it as V max ok. Now, what do we call it as an associative strength, it is what you are in reality what you are actually measuring is the animals behavior is the response that the CS acquires in the absence of US that is what actually we are measuring. So, if you measure that and then (Refer Time: 05:50) there seems to be a maximum limit beyond which no matter, how many times you keep repeating the CS and US the animal is not going to change its response alright.

So, that is that is a very very outright assumption in this model. Now, in a bit you will realize why this is relevant in terms of the experimental observations that we have seen before. However, let us ask why would that be the case in mythological sense. Now, think about this definition of US demands that the US has a response a behavioral response right; US is defined as any stimuli that can elicit its own response in an animal in the context in the setting. Now, that magnitude of that response is fixed that does not change, because it is a native response assuming that it does not change so, in assuming things do not change around that so, it is fixed it does not change.

Hence, response you are that the US is trying to mediate right, what this is all about is that you are taking stimuli CS, which by itself does not have its response. And, when presented together with the US you are attaining this new response which we call it a CR, may or may not correlate with the UR alright.

In such a case there is a natural limit of maximum right it cannot exceed, I mean it cannot exceed the maximum response that the US by itself has solicited. I mean implicitly I meaning that the see UR and CR could be same but that is not the case here, I am saying even if they are different, there is a maximum limit that the US is establishing itself for the UR.

As a result if that is driving the CS CR media mediating the CS UR CR a response that my it is only natural to has think of that might will also have a maximum response ok, it is very very handy and for sure you will see how meaningful it is when it comes to explaining some of these experimental results. The second point it says that the model says that there is for in every exposure to this CS and US, there is something called as a surprise, a surprise that the animal experiences.

And they call they quantified this amount of surprise as the maximum response that one could possibly have, we know that from the first point that is V max right. For a given US, independent of any CS that you try to combine there is a maximum response and that maximum response is V max. As a result you can think of a surprise being that is the maximum possible response difference what my current responses.

My current response kind of reflects my expectation initially when the CS name and then I am for the first time experiencing this CS US combination I do not have any response other than the response elicited by the US itself, that being the case if CS if the UR and CR are different. Then I have a way to quantify I mean my surprise as V max minus V T. If you actually look into the slide we can see the quantity V max minus V T really captures the surprise that is my assertion here.

Because, this reflects how much I could respond hypothetically and this is how much I am responding right now. So, the difference tells you how surprised I am right. So, let us keep that notion of surprise in mind, then let us see why is that why is it important to define a surprise. It is important to define a surprise, because this is a model that tells you about learning right, how do we learn and develop an association. So, that I am going to relate very directly to this surprise. Third point, third assumption is that the rate of learning is directly proportional to the amount of surprise encountered in the given trial alright.

So, if you think of learning as a process right as a process that happens over several trials, trials here meaning several exposures of CS US combinations, then at for each exposure or in each trial I am going to learn something and the amount of that learning is proportional to the surprise. So, that is what this third assumption is about third in this model, if it is proportional then there is something that need to that we need to put in proportionality constant, that sets the equality in that brings in the equality right.

So, now, that we call it as an associative constant we will see in a bit when we actually crystallize these ideas into a mathematical equation. But, the point here is I am going to bring in a notion of proportionality constant or account constant that determines the relationship, or that brings in the equality in between the relationship of the surprise to the learning ok. That is all it is about the third point. On the 4th and the very important point being, if there is a compound stimuli what is a compound stimuli. Compound stimuli is a one where we are actually presenting multiple or a combination of different stimuli right a tone, light, a flavor, smell, except all of them together forms what do you call it as a compound stimuli.

For simplicity let us think of us to come to individual CS s a and b and in a compound stimuli the current strength you the way you calculate the current strength is sum of contribution of all the CS that is the key here. Why is the current strength important? We said the current strength comes into play in estimating the surprise right that is this V T that is the current strength and we say that V T is sum of V a plus V b in a compound stimuli. For example, a could be tone b could be light, in such case we would say this V compound in a given trial we call it as capital T to distinguish from small t which is often associated with time.

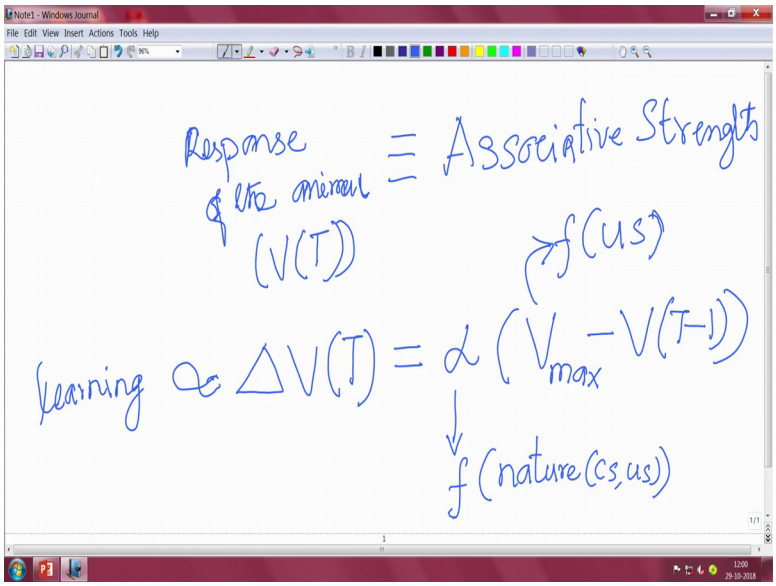
So, V in a compound trial for a given in a compound stimuli in a given trial T is given by V tone plus V light, then one can write the surprise as or the amount of surprise as being equal to we know it is directly proportional. So, clearly directly proportional to V max minus V tone plus V light it is proportional. So, we have to set it equal so that is given by some alpha here proportionality constant. This kind of summarizes the entire Rescorla Wagner model, now how useful is this in predicting or in capturing the observations that we have seen so far and in turn predicting new ideas or concepts that we have not seen so far.

A model is good only if it can give big if it can make predictions that have not been tested so, far and which we can go ahead and test it granted this is an old model so, clearly what when I am saying this the model has been tested. But however, from the point of view of Rescorla Wagner when they were developing the model the question that one would like to ask is can we capture all those experimental observations that we have seen so far in these models.

If so that is good in addition can I go ahead and get something more from this model, if it is not giving you more than what uses this model or for that matter any model right. So, that is the notion in when you are developing any model or any framework then you need to be able to make some predictions, which are really worth testing and its useful for making future making the future studies easier right.

So, let us capture this in a let us rewrite this in a very nice and concise manner and then dissect it out, one at a time what these features are and with an example small example and then let us go back and see how this nicely explains the various aspects that we have seen. Now what we are going to do is; so, we are going to measure are we going to observe the response exhibited by the animal right.

(Refer Slide Time: 16:31)



And let us call that as, that the we will equate the response of the animal, we will equate that to associative strength right that is a good reason for it, because it is only because of this association the animal is developing this response right. As the animal is developing

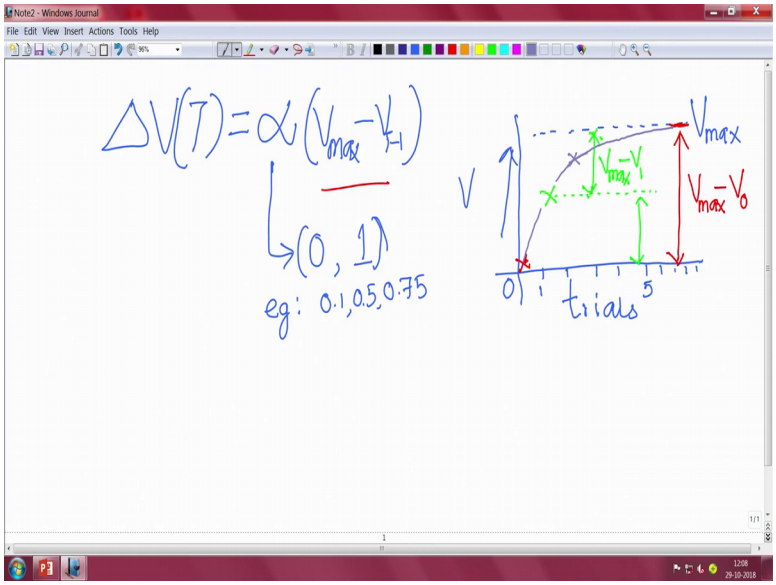
a response I mean developing in we making an association between the CS and the CR the response the CR magnitude goes up.

So, if you do measure the response of the animal it is a good reflection of the associative strength. We are going to call that we are going to call that as V and we are going to measure that as a function of different number of trials T ok. So, given that then let us go back and then rewrite our expression of learning for a single trial that is given by, the change in the response right that is happening at the trial T is equal to alpha times the surprise element, which is V max minus V until then which is let us call it as T minus 1.

So, now that you this is written in what is called as a difference equation form in this case we are actually measuring the change in the associative strength, that is that is that I am going to equate it to learning in that trial ok, learning that result from the trial T. Now, you can see oh let us make sure that alpha S and my proportionalities do not mix up so, I am going to erase this and then I am going to write almost like an infinity here for proportionality.

Now, what does this tell you I told you the we have told you that this is a function of two things the nature of the stimuli that we have the CS and the US right, the CS and the US combination right and this is totally they are function of US alone. So, if that is the case then let us try to see what happens as we progress in the trials.

(Refer Slide Time: 19:35)



So, let us go to a fresh board where you can see what I am going to do now is on the right hand side, I am going to plot what might happen to the response as a function of the number of trials ok. We are starting at 0 here and in the y axis I am going to follow the response I have abbreviated as R actually to be consistent with our notation we would call it as V.

So, write this expression once again delta V in a given trial T is equals alpha times V max minus V T minus 1 ok. So, now, what it tells you is that for a given association so, clearly there is a maximum that is sent but I have decided that is going to be my newest. So, let us mark that out maximum as V max here. Now you can see and then let us mark out since these are different difference equations let us mark out precise numbers here 1 and 2 3 4 5 and so on and so forth.

Now, if you do that we can see initially all right initially the amount of surprise is very high. Why? Because, the animal is sitting somewhere here let us mark it with the red cross the animal is initially sitting somewhere here right and that is the animals response; however, the animal could potentially respond till this point.

So, V max minus V T would be that big right during the first trial. So, if you mark it that will be my V max minus V 0, this entire surprise does not go into the learning of the animal right that is what alpha ensures the alpha ensures that it is not the entire surprise that goes into the learning. Just hold on for a minute if you are wondering why is it not the entire thing, but it is something else hold on hold on to the thought for a minute, but the point to note here is it is not the entire thing, because the alpha takes in values from 0 all the way up to 1 that is alpha is a fraction ok, it between 0 and 1 ok.

So, the proper way to say is it is defined in this interval 0 and 1. So, it can take values such as 1 10th half 3 4ths so on and so forth these are the example values of alpha, which means even though the surprise is V max minus V 0 this big as I marked in the red at the end of the first trial depending on which of the values of alpha that we choose, let us call it as one alpha whatever the value that we choose, it is going to be at that point.

So, let us when it comes for the next time let us mark it out it being there, maybe we will use a different color here let us mark it out at trial number 1 its somewhere around here. So, this represents the learning that has incurred in the first trial. However, for the next trial the subsequent trial that is learning in the second trial, when because you brought

the animal back and once more again at the beginning of that first trial the green cross represents the response good. So now, how does the change because of that experience during that first I mean second exposure ideally, but during the first trial. So, I mean after the first trial.

So, what happens is that during the second exposure the surprise element now is given by this gap we define it as V max minus V 1 all right. These times the alpha just the way we have measured here it is the way I have taken it roughly alpha is equal to half. So, half of this will be getting carried over into the learning when the animal comes for the third time or during the second trial alright.

Let us pick up color here that is navy blue. So, when the response during the third exposure would be somewhere around here. Like that the animal would eventually, as you can see that the amount of surprise progressively goes down, because it is not like it completely vanishes but it progressively goes down right.

Like that eventually the animal will reach a V max you call it as a it asymptotes to to a V max. Now, that once I draw it you will see hey yeah, that is my common learning curve that I have seen, it makes sense, but this did not come out until Rescorla and Magnan made those models and explained it. I will leave you with a teaser just like every other lecture that, this apparently simple model, apparently simple this is very very good in capturing every single thing that we have discussed so far. And, we are going to see in the next lecture how exactly this is happening good.

Thank you.