

**INTRODUCTION:** The following content is provided by MIT OpenCourseWare under a Creative Commons license. Additionally information about our license and MIT OpenCourseWare in general is available at [OCW.MIT.edu](http://OCW.MIT.edu).

**PROFESSOR:** Anyway. If you're sitting there saying, what are they talking about weird thing in the syllabus. This suggests you didn't read the syllabus, which is why we put the weird line in the syllabus about -- what is it -- what a warrior your mother would have been. That sound faintly familiar?

**AUDIENCE:** No.

**PROFESSOR:** Well it should sound familiar from reading the syllabus right? Nobody's got a clue where it's from right?

**AUDIENCE:** No.

**PROFESSOR:** Except for Rachel. I know Rachel knows, because I told her today. And obviously I cleverly arranged for it not to be something that could be Googled. Because several years ago when Google appeared, I had a line in there to make sure people were reading it and, you know, within 10 seconds of handing out the syllabus, half the class said, oh yeah that's from like Richard the third or something. So this one couldn't be Googled.

It is in fact from a book by John Steinbeck. You probably all read some Steinbeck in high school. Those of you who are fans of Arthurian literature might want to read his rewrites of the King Arthur or chunks of the King Arthur story. And when you do, you will discover that that line about thinking about what kind of a warrior your mother would have been is in there. Great book. Any other questions of similar moment that I should be answering at the present time? No. OK.

Well what I'm going to talk about today is more of the detail, if you like. Last time I had up on the board this business about you're a slave to the environment, you're a slave to your brain. Well this is the details of the way in which you are a slave to your environment. Now typically that is the heading of the title of the lecture is something like learning the chapter is learning. You're here thinking that what you came to do today is to learn. And that's not what we're talking about. The sort of learning that you are doing here is material that really gets covered in memory. I present material to you, you store it in memories somewhere. At the appropriate time you retrieve it from memory. We'll talk about that in a few sessions down the line.

What I'm talking about today is a particular form of learning, which you can think of as association learning. A very reflective form of learning. A form of learning that is phylogenetically very old. It shows up in essentially any beast you care to try it out in. Those of you who are budding neuroscience sorts, if you were to go to Eric Kandel's website and look at his Nobel Prize lecture -- because he won the Nobel Prize. You don't usually poster your Nobel Prize lecture until you win it. Because little arrogant otherwise. He won the Nobel Prize for working out the details simple association learning. Initially, his work was done in a beastie known as *Aplysia* or a *plysia*, which is a sea slug. It looks like a dill pickle and has just about as much personality and brain. But it is capable of this form of learning.

It's a gorgeous lecture. Nice art on the website. if you're going to give a Nobel Prize lecture, you kind of don't want to waste it. So I heard him give a version of this it a different meeting in Australia, and it's a good lecture. All right what kind of learning is this that we're talking about. How many people here like strawberries? Some people like strawberries some people don't like strawberries. Now you did not come into the world knowing that fact. You now know that. And I do not think that most of you learned that fact, you know, like in the circle time at preschool. Hello children today we're going to decide if you like strawberries. You like strawberries. You don't like strawberries. They make you, you know, break out in a rash. Whereas no right? You learned about your taste for strawberries in some different way. You learn that you should, you know, dive under the bed when you see a flash of lightning. Because you're scared of the thunder. You learned about that not because you went to thunder school, but because you learned about the association. You picked it up from the environment.

And it's that sort of association learning that I'm going to talk about today. I'm going to talk about two different versions. One of them is learning associations between stimuli in the world, traditionally known as classical conditioning or Pavlovian conditioning in honor of Ivan Pavlov. The other is the learning the associations between what you do and the consequences of what you do, often called operant conditioning. Sometimes called Skinnerian conditioning in honor of B.F. Skinner, one of it great practitioners.

Now let's start with this stimulus form of learning. The basic classical conditioning experiment is one of those experiments that people know about before they come into a psych class typically. That's Pavlov and his salivating dog. What Pavlov was doing was studying digestion. And dogs were his animal of choice. In fact he's also a Nobel Prize winner, but his Nobel Prize

lecture -- well it probably is posted on the web somewhere. But anyway he won the Nobel Prize for work on the digestive enzymes in I think the stomach. He then decided he was interested in digestive enzymes in saliva. And he needed a supply of saliva. Where you're going to get saliva from? Well what he did was he put a little cannula, a little hole, in the cheek of a dog, and a little collection tube. And then he took his dog, put him in a sort of harness and sprayed powdered meat into the dog's mouth. If you spray powdered meat into a dog's mouth, the dog does what? The dog salivates. And since the dog's got a little hole in here some of the saliva drools out. And you can go off and study it.

What Pavlov discovered that was of interest to him -- it turned out to be of interest to him -- was that he'd get up in the morning, grab the dog, put the dog in the harness, and the dog would start salivating before any meat powder showed up. Pavlov's thinking, hmm I can save on meat powder.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** But the difference between the rest of us schlumps and Nobel Prize winning guys is when they see something interesting, they know that it's interesting. And what Pavlov figured out is the dog is anticipating the meat powder. The dog has learned that this situation means meat powder in some fashion. Gee that's actually more interesting said Pavlov than dogs drool. I'm going to study that for a awhile. And so what he did was he set up the more familiar form of this where -- let's introduce some terminology. He had food, the meat powder. We will call that an unconditional stimulus. The characteristic of an unconditional stimulus is that it produces an unconditioned response, saliva in this case, without you having to do anything. You know, get your off the shelf dog. That dog's going to drool for you if you give it food.

Then what he did was to pair that unconditioned stimulus with a conditioned stimulus, like a bell or a tone or something like that. So now he was going bell, food and the dog obligingly drooled. Bell, food, drool. Boom, boom, boom, over and over again. Then the critical thing to do is you do just the bell by itself and skip the food. What do you discover? You discover that the bell by itself now produces the saliva. And when the conditioned stimulus alone is producing the response, we call that the conditioned response. The animal has learned an association between bell and food. And you're seeing that learning by measuring this conditioned response. That kind of learning, which is what Kandel was studying in *Aplysia*, is presumably reflexive, automatic outside of the realm of consciousness even if I fall into sort of sloppy kind of language later. Understands that the dog is not presumed to be sitting there

thinking hmm bell, what does that bell mean? That bell symbolizes for me the appearance of. Nah. Reflexive happening automatically. Doesn't matter what the, you know, what the dog does or does not think. Indeed you can fall victim to this sort of thing.

Quite apart from your conscious, wishes, desires, whatever, there's a vision researcher sort of a half of generation older than me who still mad at me. Because 30 years ago I couldn't escape being conditioned in this fashion. Back in those days the apparatus when you were putting up a visual stimulus made a noise. I was supposed to push one button as quickly as I could. One button if I saw something, and another button if I didn't see something. But every time he put up a stimulus, the apparatus went click. And I just would hit the stupid button. I had learned the association between click and the stimulus. And, you know, my little sea slug brain was refusing to be overridden by this, you know, great big conscious apparatus of this guy wants me to look for some really boring thing. And he's still mad at me. It's very, very sad.

OK. This is a very ruled governed behavior. In fact it probably says that on the handout. No it says what's being learned here. It's a very ruled governed behavior. Pavlov himself worked out many of the rules, and then a large body of research afterwards continued that effort. And let me tell you about some of the constraints on this form of learning, and then explain a bit about how it is that this might actually have anything to do with learning more interesting things. What the sea slug learns is that gee when I sense shrimp juices I recall in the water, that means somebody's going to poke me. So I should retract my gill. That's the response that the sea slug makes, to retract its gill. The response the dog makes is to drool. I mean that's nice, but how does that relate to anything like human behavior?

So let me tell you a few of the constraints on it. First a constraint that's really more like an advertisement for next time is to say that we talk about these conditioned stimuli out there. In this case the bell. Even something like deciding what the stimulus is, is not an entirely trivial business. So suppose I was to come in here with a rabbit let's say. Come here with a rabbit. Every time I walk in with the rabbit, I activate the electric grid that's in your sea. And you all get a little zips. And, you know, you jump in the air. Eventually I bring the rabbit in and what happens? You jump without me having to bother running electric current through your posterior.

What's the stimulus there? Well we sort of naturally would say it's, you know, it's the rabbit. And it could be the rabbit's ear. It could be rabbit ear combined with blackboard or something

like that. It turns out that we have natural, and animals have natural, ways of carving up the world into stimuli, into objects perhaps. And when you're trying to figure out what's governing the behavior in animal, it's not even immediately trivially obvious what that stimulus might be. That's what we'll end up talking about for the next few lectures after this. But sticking with the realm of the constraints on the learning itself, one important constraint is that you have to notice the relationship between the conditioned stimulus and the unconditioned stimulus.

One version of that is completely trivial. If I use a very quiet bell that you can't hear you don't learn anything about it. You know big deal. The more interesting case is illustrated by a phenomenon known as overshadowing. Suppose what I do is I have to stimuli that appear at the same time. This bell and a light. A nice little, you know, little LED d or something like that. So bell and light followed by food. Bell and light followed by food. Bell and light followed. There's a loud bell and a little light. Got it? OK what happens in this situation is that when you play the bell by itself, you get salivation. When you play the lights by itself, even though the light was always followed by the food, you don't get salivation. Because the light has been overshadowed -- that's where the jargon comes from -- the light has been overshadowed by the presence of the bell.

What's the critical control experiment in an overshadowing paradigm? What do you need to know here for this to be interesting? Yeah?

**AUDIENCE:** [INAUDIBLE]

**PROFESSOR:** You have to do a training session with some other dogs or rat or something with just the light. You have to go light, food, light, food, light, food, and show that this relatively wimpy light -- if presented in isolation -- will produce perfectly fine learning. In the interesting version of the experiment, that's in fact the case. But when you present, you know, bell and lights together, the stronger bell captures the learning and the weaker light loses. So, you know, is a silly example where I was bringing in a rabbit. You know, if the rabbit was, oh I don't know, wearing a little silver ring or something like that, you'd learn the association between rabbit and shock, but, not the association between ring and shock perhaps because it was too small. It was overshadowed as a stimulus.

It is also critical that the CS predicts the US. Did I get that right? Yes. The conditioned stimulus has to predict the unconditioned stimulus. It is not adequate simply for the CS to just show up every time the US shows up. So a silly example, everybody who bombs the midterm in this

class, almost everybody maybe it's not perfect but it's a pretty good association, almost everybody who bombs the midterm in this class drank something shortly before doing that right. So drink, bomb. And it works every year. So there's a lot to pairing. Drink, bomb. Look, I wouldn't on the basis of that give up drinking. There's no predictive value there. Because you drink a bunch of times when nothing has anything to do with the midterm. There's no relationships.

What's important is a contingent predictive relationship. This is a brain mechanisms that's there to learn what in the world predicts what other thing in the world. In the standard Pavlovian set up here, the prediction is perfect. Every time you ring the bell, you get the food. If you cut that down so that the prediction is imperfect, sort of correlational, you'll still learn but you'll learn less and you'll learn more slowly. So if, you know, half the time the bell rang you got food, and the bell never rang any other time, the animal would learn that bell more or less means food. But it would be slower and less strong. That's not what I wanted to move. You know, been speaking of learning, I've been teaching in this room for years, and I have still never managed to reliably use these boards. Always push the wrong button.

All right. So suppose if you've got a good strong, you know, bell, food, bell, food, bell, food kind of thing, what you're going to do is over time you build up a rate of responding to some sort of asymptotic level. What happens if you change the contingency? Most particularly what happens if you stopped feeding the dog after the bell?

**AUDIENCE:** The response will go away.

**PROFESSOR:** Oh the response will go away, not the dog. The dog doesn't have the option in this particular case. Yeah. The response will go away. That's known in the conditioning literature as extinction. The response will extinguish. I mean that makes sense right? You know, if the contingency no longer applies, why should I continue to respond on the basis of a contingency that's no longer valid. Did you forget, you the dog, did you forget that contingency or unlearned that contingency? Is it gone? The answer is no. It still seems to be there in some sense. It's just you're no longer making the response. How do we know that? Well for instance, if you were to give the dog a little break, send him home, then put him, back in the apparatus. You would discover that the response, even if you never presented anymore food, the response would come back and then extinguish again. This is known as spontaneous recovery. And, you know, to use the language that we shouldn't be using, it's like the dog saying, all right, you know, all right bell predicts food. Oh bell doesn't predict food anymore. I

mean it's not like I forgot that the bell used to predict the food. I'm not a dumb dog, I remember that. But it doesn't anymore, so why should I drool. OK.

Now so I wonder what situation we're in here. Are we back here or are we here? Well we'll drool a little bit just to see. Again the dog is not presumed to be doing anything like that kind of thinking. But it's not that far off from more complicated situations that you could imagine in the real world. So you develop a relationship with another person that produces some rate of conditioned response or something like that. Because, you know, while you're responding in any case. Then he decides not to have anything further to do with you. Response disappears. Then comes, oh I don't know, summer vacation. And you see her again after vacation. Do you remit a response? Well are we here, or maybe we're back here.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** So you know, maybe a little response. So that's spontaneous recovery. The original notion was sort of that you were general purpose association learn, you can learn anything. The evidence from preparedness, which I talked about before, suggests that you are better prepared to learn some things than others. So you're better prepared to learn that snakes are scary than that bunnies are scary, for instance. It's fairly general purpose or at least there are aspects of association learning that seem to be general purpose, but not all of it is completely general purpose.

One thing that you're certainly set up to do is to notice associations only over a limited time window. Oh I lost underneath there. Right. Tone followed by food. Tone followed by food that's the CS followed by the US, right? So let's take this asymptotic points here and plot that over here. Now suppose that we systematically vary the relationship in time between the conditioned stimulus and the unconditioned stimulus. Well this is on the order say of one or two seconds. If I ring the bell today and feed you tomorrow, how much learning you figure we get?

**AUDIENCE:** [INAUDIBLE]

**PROFESSOR:** Not a lot. First of all it's a very long boring experiment, since we need lots of pairing. But basically you don't have to go that far. But it's going to fade off in this direction. That you can't have too long a period between the conditioned stimulus and the unconditioned stimulus. Zero doesn't produce much conditioning and negative relationships. So I give you food and then I ring a bell. That says, you know, food that was food. Food that was food. You know OK. It

doesn't hit zero at zero, but there's really basically very little happening down that way. So there's a narrow time window within which this chunk of you is looking for associations out there in the world. The the world example here might be bump signs on the highway. When is a bump sign on the highway useful? If the bump sign shows up at exactly the same place as the bump, thank you. You want it to show up a little bit before the bump. If it shows up after the bump, you know, that was a bump.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** That's not that useful. So it's limited constrained in time. Now how can we go and get from this nice rule governed behavior to more complicated behaviors? One way to see how that might work is a paradigm in the conditioning literature known as century -- did it again didn't I look at that, got it got it wrong on both dimensions -- called sensory preconditioning. I'll just restart this over here. It's easier. Here's how a sensory preconditioning experiment might work if you were a rat or dog or something like that. So step one. I'm going to show you a light. And then I'm going to ring a tone. I'm going to do that a bunch of times. Light, tone, light, tone, light, tone. Then I'm going to play the light alone, or I play the tone alone. Do you salivate? No, why should you salivate? It's got nothing to do with validation. Step two. Tone, food. That's just the classical conditioning paradigm. Tone, food, tone, food, tone, food. Play the tone alone. Well tone food whoops. Saliva. So now I'm going to play the tone alone. And low and behold, we know I'll get the conditioned responses of salivation here.

The critical test is now I play. I show the light in isolation. What happens? Well what happens is that you get the conditioned response. The animal will now salivate in response to the light alone. Why is this interesting? Well what's the animal doing? Well again we can sort of think in sort of conscious terms that aren't appropriate. The animal is saying, light. I know about light. Light means tone. Ah ha tone, I know about tone, tone means food. So if tone means food, I should be like salivating. And if light means tone, I should be salivating there. So I think I'll just start, you know, drooling all over the place now.

What's important about this is actually you can see sort of graphically here. I'm managing to get more remote from the response. I'm working my way backward. Suppose it was the case that at the end of every one of my lectures around 3:23, I was to say in summary. And that your habit was to immediately run out of class thereafter and get yourself a snack. You might discover that as I said in summary that somebody walked in.

**AUDIENCE:** LAUGHTER]

**PROFESSOR:** You might discover that as I said in summary that you start to feel hungry, because of a learned association. It might never occurred to you until you examined this, why you feel hungry when I said in summary. But if we look at this timing thing, it's not the case that I say in summary, and one second later I blow M&Ms into your mouth or something like that. You've got of somehow explain how you work backwards from the eventual M&Ms here back to something that I said. And this is one way to do it. You imagine that what you've got is an automatic association learner. Its job is to look for sort of if a then b situations in the world. And that it is capable of chaining those together. That you can go if a then b, if b then c, if c then, you know. Oh hey look if this then this thing way down the line somewhere.

And if you can start chaining these simple associations together, all of a sudden you've got the possibility of having a much more complicated kind of tool that could potentially explain much more complicated kinds of behavior.

So that's classical conditioning. Good for explaining or good for talking about relationships between stimuli out in the world. Another thing that you would want to learn about is the relationship between what you do and its consequences. That is what we talked about a bit last time when I did the Thorndike puzzle box example. You know Thorndike's cat was not so interested in learning about relations of stimuli in the world. What it was interested in learning is if I do this then I get that fish. And that's the core of operant conditioning.

Now I took this course once upon a time, but I took it at Princeton where I was an undergrad. And that allows me to encapsulate the basic difference between a Princeton undergraduate education -- look at that, there's a guy wearing a Princeton sweatshirt right now. Don't cover it up. You know unless she's no longer talking to you. That's extinction curve over there. Anyway where were we. Oh yes. The difference between a Princeton education and a MIT education is that at Princeton this course satisfied the science requirement.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** You laugh. But if I was to give this lecture at Princeton and say at MIT, this course satisfies a sort of, you know, humanities literature kind of requirement, they'd all laughs. So the main difference between the courses was not in what, you know, the guy standing up front did in the way of lecturing, but here of course to make it a Hass course you do a lot of writing. And at Princeton it was a lab course. And it's a great pity in some way. It's excellent that you are off

writing, but it's a great pity not to have a lab component to this. Because this operant conditioning thing is a lot cooler if you got a pigeon of your own. Which is what we had. You don't end up with a salivating dog of your own. But pigeons are OK. So the version of an operant conditioning experiment that people tend to know something about before they come into a courses, is a so called Skinner box. Which is, you know, a pigeon.

**AUDIENCE:**

[LAUGHTER] He can be a rat too if you want. It's just a matter of where you put the whiskers. Anyway the idea of a Skinner boxes was you'd have an environment that could really control the options available to the pigeon or the rat. And what you'd have in a pigeon Skinner box is a box that had nothing much in it except for a key here that is hooked up to a little micro switch or something. And that the animal could peck at. And we could record the pecks. And a little bin down here where the bird seed could show up. And stick a pigeon in there, and this is a hungry pigeon because you haven't fed it. And so yes, a bummed out pigeon.

But if he pecks there in the right ways we'll feed him. So this is simply the somewhat higher tech version of Thorndike's puzzle box you'll recognize. The pigeon has to figure out to peck a the key. If you just stick a pigeon in a Skinner box, even a hungry pigeon, the pigeon just sits there. I mean, you know, does stuff. But the pigeon doesn't immediately say, hey I've taken intro psych I know about this, I'm going to go and peck that thing. You have to do what's known as shaping its behavior. The first thing you have to do that's important, you have to get your pigeon from the basement to the fourth floor, where the lab was. And should you every need to do that, the important thing to know is that plastic juice containers are really good. You take the pigeon sticking it head first in the plastic juice container. Not with the juice in it.

**AUDIENCE:**

[LAUGHTER]

**PROFESSOR:**

And then the pigeon is actually quite calm under those circumstances. If you decide how tough can a pigeon BE, and you don't need to do that because you can't find your juice container anyway, and you grab your pigeon because you're bigger than the pigeon. Try to carry it upstairs, what you end up with is lose pigeons unlike the second and third floor. So things that you're going to miss out on just because you're writing papers instead.

What you do once you stick that pigeon in the Skinner box? If you just sit there, it's going to be a long day. What you have to do is to shape the pigeon's behavior. Probably says shaping somewhere on the handout. Yeah use the law of effect to shape the animal it says there. That doesn't mean like grr. What it means is that the pigeon's just sitting there moving around doing

pigeony like things, feeling hungry. And the pigeon turns towards the wall that's got the key on. And you push a little button that gives him a little bird seed. He goes and eats the bird seed, and goes back to doing pigeony things. But now the law of effect's working. That bird seed is a positive reinforcer right.

So the chunk of the bird's brain that is doing this association learning between action and its consequences saying, birds seed that was good bird seed. I like the bird seed. What do I do to get more bird seed. Well it's not saying that explicitly, but it's saying we'll do whatever we were just doing. OK. Well now you don't want him to just be looking at the wall. So now after a couple of rounds of that, you say, OK bird you only get the bird seed if you move a little closer to the wall. The bird moves closer to the wall all right. All right now you only get it if you're looking at the key. Now you're only getting it if you're right up there. And eventually you get the bird pecking at the key, and then you can go off and do other cool experiments from there.

But you have to shape the behavior in the way you want. And the key business. I mean there's a key. There's the bird food. That's somewhat arbitrary. It's just, you know, what Skinner wanted to use to control the birds, you know, to make it possible to measure the bird's behavior. We had a very clever pigeon when I did this lab. And we got through the stuff that was in the lab book like really quickly. Probably because the pigeon had been the pigeon for a half a dozen other, you know. Oh yeah, yeah I'm supposed to fake it here and claim I don't know what's going on here. All right yeah. Oh good we're shape now give me the food.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** But anyway. We still had some time. We thought well we'll mess with this pigeon. And so we started reinforcing the pigeon for turns. So, you know, no bird seed unless you make a quarter turn, OK. We eventually had the bird making three full turns for each. And that sort of staggering over to the bird see.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** But we had this great ballet dancing pigeons. And that's in fact the basis of trained animal acts that you may have seen at various places. And I should advertised that it's not confined to pigeons and things like that. You can perfectly well condition human beings. I already think I've used in the last lecture the example of jokes as a case of behavior getting shaped. Jokes that get rewarded with laughs get repeated. Jokes that get rewarded with smacks don't get repeated. But again going back to my intro psych class, I should tell you that it is possible to

condition the professor. What you need to do is figure out well what reinforces professors. The answer, at least in this sort of a setting, is students who look kind of interested, and smile and write notes. At least that's what my a professor, who was in fact an important learning theorist in his own right, that's what he told us. He said it's reinforcing if you're looking like you're interested and you're writing notes. And so you should, he told us, be able to pick a behavior that the professor is doing, and reinforce it by smiling and writing notes at the appropriate time.

So, you know, I was going to be a psych major. I did what I was told I was sitting about there. My friend and I every time, the next psych lecture, every time Professor [? Cayman ?] moved to the left, we smiled and took notes. And by the end of lecture he was most of the way out the door.

**AUDIENCE:** [LAUGHTER]

PROFESSOR: It was great. Now as evidence for the notion that this is quite unconscious and reflexive kind of learning, we told him about it afterwards. And he absolutely believed that it was possible that it happened, and absolutely reported no awareness that it had happened. So you're welcome to try this. Your even welcome to try it here. Let me tell you that I have made this offer in years past, and nobody has reported a great success. But the great failure was when one recitation section got together and decided their strength in numbers. But it turns out that if everybody in a recitation sits -- I still remember they were all sitting there -- if you all sit in one place, and I don't remember what I was supposed to do. But when I did it, they all went [INAUDIBLE]. I kind of cracked up, but I don't believe I learned anything particular.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** But it can sit out there as a challenge for you. If anybody gets it to work on, you know, the math guy or something. Is Arthur Mattuck still teaching?

**AUDIENCE:** No.

**PROFESSOR:** 18, O whatever?

**AUDIENCE:** [UNINTELLIGIBLE]

**PROFESSOR:** 1803 in the spring. Oh that's too long to wait. I've never been sure Mattuck will notice anyway.

But that's a separate issue.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Anyway if anybody succeeds in conditioning there professor do let me know. The points here is that this is a form of learning that does apply in the human world as well as in the pigeon world. Once you've got that animal shaped to do what you want, you can then start studying the rules that govern that behavior. Let me say a word about schedules of reinforcements, since I see that it's there on the handout. Actually it's doesn't say schedules, oh it does. Fix and variable ratio and fixed and variable interval schedules reinforcement. What that means is if you're reinforcing the pigeon every time he pecks, he's on a fixed ratio 1 schedule. You shape up the behavior, and at some point the pigeon is trained. And if you're reinforcing him every time he makes a peck, he will emit pecks. So let's call this the peck rate. He'll emit pecks at something some asintotic rate, not unlike the salivation thing over there. Actually I want to save myself a little space here. So let's only go this far. So an asintotic rate of responding.

Now suppose that you change the rule. Suppose you say, well you can say it to the pigeon because the pigeon won't understand you, say to the pigeon, OK now you get reinforced only every 10th peck. What's the pigeon going to do, do you think? How's the behavior going to change?

**AUDIENCE:** [INAUDIBLE]

**PROFESSOR:** It's going to go squiggly, apparently. No, every 10th peck, not every 10 seconds. I'm interpreting your squiggly as the answer to a later question. So save the squiggle, it'll be good.

**AUDIENCE:** Peck faster.

**PROFESSOR:** Peck faster. Whoever said that, that sounds good. Well if you've gotta work harder to get the same reward, you're going to end up pecking faster. Right? So if you sort of think about it in terms of your once upon a time, you could get an A in whatever. You know writing. For writing like my eight year old wrote this morning, seven sentences of at least six words each. Took him all of breakfast to do that, because he'd lost his book. An anyways it's a long story. But, you know, so he emitted his writing behavior to relatively low rate. If you emit your writing behavior at that rate, you guys are going to be in serious trouble, right? To get the same reward, you now have to produce more work. And as a result you'll crank up the level. So that would be a fix ratio. What I was describing every 10 pecks, that would be a fixed ratio of 10. A

variable ratio is on average every 10 pecks you get reinforced. And that actually produces even higher levels of responding.

Now what the squiggle was the answer to is what happens if instead of a ratio schedule, you have an interval schedule? Suppose you reinforced the behavior only for the first peck after every minute? Make a different graph over here. So a bird can peck it all they want. But only when they peck after this interval, marker goes by or they're going to get reinforced. Well I mean a pigeon with a wrist watch is going to look at his watch and say, hmm. Pigeon doesn't have a wrist watch of course. But they do have an ability to estimate time. And so what they do, you know, immediately after getting rewarded, they just sort of sit there. So this is again going to be rates of response. They just sit there, and then they say, it's like a minute gone yet nothing happened. Got to be now. No, no, it's still not. Oh it's coming. No, no no. Boom.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** And you get this very scallopy behavior. Now if you don't think that has anything to do with human behavior. Well first of all you can ask yourself about your writing output. So for instance there's a paper do on a sort of a regular interval.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** A smart pigeon would be emitting words at about that rate right? Well actually I did meet a student who claimed he was doing that. More power to him. But I think most of view, you know, it's do friday? I think this point here is like Friday 4:00 pm or something. Anyway. Or you come to my house where if you're an eight year old you get your allowance on the weekend, right. But only if you do your chores. So Monday is my kid asking what chores he should do? No. Saturday morning? You bet. What can I do? What can I do? You know make my bed. I made my bed. Can I lick the floor now, you know.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Oh and the downside of this is one of the reasons for paying people on a Friday. Is that if you pay them on a Thursday, they don't show up on Friday. Even though at some level they're much more likely to be sick on the Friday if you pay them on the Thursday. So you want to pay them on a Friday and then they can be sick all weekend on their own time.

So that's what we mean by schedules of reinforcement. This is also, operant conditioning, is also a very rule governed behavior. It is governed by rules that are in many ways similar to the

rules for classical conditioning. Let's just do this one as an example. It's probably later on in the handout. So I reward little all old every time he pecks the key. Now I stop rewarding and what happens to the behavior? I take that boom to mean, yeah, it extinguishes. If I give him a break, I'll get some spontaneous recovery and it'll extinguished again. Just like you'll get in classical conditioning.

What happens in these? How does the extinction compare in a schedule like this to a schedule like this? How about a hand? I'm hearing good mother mutterings but nobody has a hand. So slower. I heard some more slower mutterings. It's slower. If that's not intuitively obvious, ask yourself about the difference between a slot machine and a Coke machine, right? You put a buck in the coke machine, you get a coke right? You put a buck in the coke machine, you don't get a coke. How many more bucks do you put in?

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Well all right. So you're not too dumb. That's good. OK. Now you go to Las Vegas you put a buck in the slot machine and you don't get anything out. What do you do? Put another buck in. Actually Las Vegas is a beautiful example of applied conditioning theory. We can send everybody on a class trip. Actually we did that didn't we, sort of. There's the best seller -- that was more applied math than applied psychology. The applied psychology thing is when a slot machine pays off, traditionally what happens is the coins come out right. Now often they're electronic, but they simulated anyway. The coins come out. What di the coins hit when they come out?

**AUDIENCE:** Metal.

**PROFESSOR:** Metal. Why do they hit metal?

**AUDIENCE:** To make a sound.

**PROFESSOR:** To make a racket. Why do you want to make a racket? Well that racket itself becomes positively reinforcing. You want to hear that sound right. You want to put that buck in and hear crunch crunch. Oh yeah this, is very good stuff.

Now slot machines. I mean you don't go out and play slot machines a lot, but you see the movies. I hope. Anyway. Slot machines are typically located in small sound proof booth? No. Where are they located?

**AUDIENCE:** [UNINTELLIGIBLE]

**PROFESSOR:** On a giant floor with thousands of slot machines. What does that mean? That means when somebody five blocks over gets a pay off, what do you hear? You hear the sound. You've been conditioned to find that reinforcing. And you are so dumb.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** They know that you are willing to being reinforced by somebody else getting paid off. And you say oh man there's money happening here let me put some more into this thing. Anyway. Lovely applied psychology in, you know, the worst sense of the word. Well maybe not the worst. I can think of a few others. But while I'm thinking of a few other worse ones, take a minute to stretch. Reinforce your neighbor. Wake up your neighbor if that's necessary.

[SIDE CONVERSATION WITH STUDENT]

**PROFESSOR:** OK. There is a sense in which you are a general purpose association learner. And have mechanisms in your brain that are basically saying, you know, teach me about the associations between stimuli or the association between my acts and their consequences. And I can be fairly broad minded about what those stimuli are, or what those acts might be. And then there are special purpose versions of these things designed for very particular tasks. Let me fish around for what's perhaps the best example of this. Is there anybody here who can think of in their life of food that they used to love, but they now hate or won't touch, and they know exactly why? Yeah out there in the cheap seats?

**AUDIENCE:** I ate a chocolate frosted cupcake when I was little. And I went home and I got the flu, and I don't eat it anymore.

**PROFESSOR:** Perfect Gee. First try no weird examples this year. Now you've got the flu. let's get a little graphic here. You've got the flu and what happened?

**AUDIENCE:** Vomit a lot.

**PROFESSOR:** Thank you that's what we needed to know.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** And not only that, we also need to know do you believe that the chocolate cupcake gave you the flu?

**AUDIENCE:** Not anymore. But I use to definitely think that.

[LAUGHTER]

**PROFESSOR:** Yeah?

**AUDIENCE:** Alright, when I was in kindergarten --

**PROFESSOR:** He doesn't care that I already have a good example. He wants to give me another cool example. All right. All right. All right. All right. It's not as good?

**AUDIENCE:** When I was in kindergarten the first day of school or the first week I ate lunch in the cafeteria and didn't eat a school lunch again five, six years.

**PROFESSOR:** This is why he's slim to this day.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Actually we'll come back to that example, it's sort of a useful function to. So she ate the cupcake, she got sick. She knows at some level it wasn't the cupcake that made her sick. But there is a chunk of brain that says, I got sick. I ate cupcake. Shortly thereafter got sick. Don't want to eat cupcake anymore. This is a chunk of your brain that is quite immune, or is actually very hard for you to talk to and say, wait a second we used to love cupcakes. Cupcakes are really good. It doesn't want to hear about this. It says, you ate it, you got sick. And this is a form of association learning. Well the original version of this was discovered by some rat who ate a cupcake and threw up.

But in the learning literature, it was studied by a guy named Garcia. So it's sometimes goes by the name of the Garcia effect, what he did was he had rats, in a sort of a Skinner box situation. And he gave them a new flavor of water like spearmint or something. And then he made the poor rats sick. Strapped it to the turntable of a record player.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** An experiment you can't do m because you can't fit the rat into the CD drive.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** And then the next day you give the rat a choice. You want spearmint water or you want this

other new weird flavor. And the rat goes to the other flavor. Says forget it, you know, I'm not going for the spearmint water. But this is a very specific form of learning. It sometimes called taster version, which is not quite right. If you happen to be a sensation and perception person. Taste, as the sensation that your tongue does for you, is really restricted to sweet, sour, salty and bitter. What you become averse to is the flavor, most of which is smell. Or perhaps in human cases, a larger context like school lunch or something like that. But there are strong restrictions on what it is that you will develop in a version two, particular if you're a rat.

So the other version of the experiment Garcia did was he gave rats a new bottled of water. And this one was flashing lights right. Water never did that before. Drink the water. Get sick. The next day you got a choice between the flashing light one, and the one that's making clicking noises or something like that. Rat doesn't care. This little chunk of brain was not built to figure out that flashing water is a problem. This is a chunk of brain that is there to tell you that it knows some things about food. Foods have flavors, and if you get sick some chunk of time after eating, you should avoid that flavor the next time, and things associated with that flavor.

Also the timing. Where did my timing parameter go? The timing is different. If you eat something and get sick instantly, nothing happens. You don't learn anything. Because this little box knows it takes a while to get sick. I think your story was ate the cupcake, went home, got the flu. Hours later she's losing it. And this little junk of brain is working back in time. It's got its own time window. It's working back in time saying, what did we eat a few hours ago? Cupcakes. Don't want to eat the cupcake. Very useful thing right.

If you were grazing, you know, an omnivore kind of animal, very useful thing to have a device that says don't eat it because, you know, last time you ate it made you sick. Oh the other thing when we were doing this tone, food, tone, food pairing over and over again. How many cupcakes did you eat? One cup cake. And you repeated this lots of time? No. Right. Because this is a little association mechanism designed to keep you alive. And if, you know, eat the cupcake almost die. You know, you don't want a bunch more pairings of eat the cupcake, almost died, eat the cupcake. Oh man that time dead.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** So one try of learning, which by the way when Garcia discovered it, it was thought to be impossible. But it's a special case of an association learning that works in a single trial. It has

its pitfalls. And in fact it's sort of cognitive impenetrability. The fact that it doesn't care what you know is a problem. So except for the seniors here, of course alcohol has not past your lips. And even the seniors have not drunk to excess. So what may be news to you is that if you drink too much alcohol you can get sick.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** They knew that. OK. Anyway drink too much alcohol you get sick right. The question is what do you develop the aversion to? A smart system, rather like this, you know, the writing example, the smart system would say I just drank, you know, 12 screwdrivers in a row or something like that. No more vodka for me. The problem is that alcohol has very minimal flavor to it, and what happens is you drink a screwdriver -- orange juice plus vodka or something like that -- you get violently sick. I'm not going to touch that orange juice anymore.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** You know. Pile of beers and a pile pretzels. You're violently ill, and the pretzels just look miserable to you. so it is a disadvantage. It's called clever that this thing is out there to save your life. Unfortunately in civilization, we have figured out clever ways to misuse it I'm afraid.

Well since it says example two of superstitious behavior, let me say a quick word about superstitious behavior. This is the best time to see what Skinner called superstitious behavior, because all you have to do is watch baseball. The Law of Effect said if something good happens, you're going to do what you were doing just beforehand. Think about baseball. What something good that can happen? You get up to the plate. You hit the ball. It goes over the fence. And you get to run around and stuff. Well what were you doing just before? Well, you know, maybe you wiped off your shoes or something like that. So next time you come up to the plate, you wipe off your shoes. Don't think anything about it. Pretty soon you're doing this all the time. Some sports writer ask you, you know, how come you wipe off the shoes every time? The plate's slippery or some story like that. You got no idea why it is. But it's probably been shaped into place by the contingencies of reinforcement.

The second best place to see this in my experience is at exams. Look around at exams perhaps. Look at yourself at exams and say, look at those three neatly lined up pencils. Points exactly lined up there. The coke has to be exactly to the left of the test paper, and the snickers bar has to be right there yeah. You know, or I'm going to flunk.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Again, if you're asked about it, the answers oh I don't know it just makes me feel comfortable or something like that. But it's again sort of superstitious behavior perhaps shaped into place by this sort of this Law of Effect kind of work. Let me say a bit more about how this applies out in the real world. Schedules of reinforcement are the sorts of things that we do to ourselves all the time. For example in child rearing. Is that actually the next example on the handout maybe? Yeah it says something about parents and children. Suppose that you were a little kid, which you once upon a time you were. and you want a cookie. So you say, can I have a cookie? And your mom gives you a cookie. And that's good. The next time you say, can I have a cookie, and it's just before dinner , SO SHE says no. So what do you? Well maybe you extinguish the behavior immediately. And you're a perfect model child, and you end up at, you know, like MIT or something like. Can I have a cookie? Please can I have a cookie? Pretty please can I have a cookie? Eventually your mom will say, oh here have a cookie right.

All right so what have you done? We now moved you from an FR1 to an FR something else, or actually it's probably a VR schedule of some sort. So now you're going to be emitting cookie behavior at a much more rapid right. Can I have a cookie? Can I have a cookie? Please can I have a cookie? I want a cookie. I want a cookie right now.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Eventually, you know, your parents get tired of this. They decide they're going to cut you off here. But you're now up here somewhere. How's that extinction curve look? Oh man, it goes out to about, you know, age 23 or something like that.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Plus parents are not good at this. So what you do is can I have a cookie? I really want a cookie. OK have a cookie. OK. So now we're on VR 2064 kind of schedule. And everybody's going nuts.

The other place you see a similar sort of example is sleeping through the night. The kid cries right. You go and comfort the kid. Put the kid back down go to sleep. Eventually you decide this little monster needs to sleep through the night, because like I need to sleep through the night. So I'm going to not get up when he cries. He's crying, I can't sleep. Crying for like an hour.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Oh maybe just this time. All right. Now you've rewarded him for crying for an hour, rather than for crying for a couple of seconds. And again you end up with a similar sort of problem. My eldest actually had this to an absolute art when he was little. Of course he didn't know it again. Because all nice unconscious and reflexive stuff. He came into the world built so that if he cried for more than a few minutes, he also threw up.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** All right. So it's, you know, besides it's time for him to sleep through the night. He's crying you're saying, oh man if he doesn't go back to sleep in a second not only am I going to go nuts, but I'm going to have to do the laundry again. But if I reward him then. I don't think they've sleep through the night yet. Is this encouraging yet? Mara is getting so depressed there. All right that you're not babies anymore. Let's give an example of the relevance of this that might have something to do closer to adult behavior.

One of the interesting realms where these schedules of reinforcement may have an unintentional, well none of it has intention to it, an unfortunate negative consequence is a phenomenon known in at least in the research on sexual behavior as getting to yes. What is this about? Typically in heterosexual relationships the request, verbal or otherwise, for some sort of positive reinforcement of a sexual nature comes from the guy and is delivered to the woman in some fashion. Typically that request, verbal or otherwise, is met with a no initially. If the relationship develops over time of course, eventually odds are that there will be a yes. Well what does that sound like? That some sort of a variable schedule of reinforcement. Oh why might that be the case? We'll talk about this more later in the term. But there is interesting evidence that guys are not some, you know, unbridal bag of hormones

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** But that they actually fall in love faster than women do. So, you know, it's the Romeo and Juliet thing right. You know, he's allegedly in love with Rosalind. He goes and see Juliet, and two seconds later it's oh she doth teaches the torches to burn bright and all that sort of stuff. Woo, he's gone.

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** And when he walks out of the party later, and meets his friend the psychologist who does a survey kind of thing. He will report he feels like he's in love. And I don't know what yet, Juliet may be a different example. I mean they all end up dead and things like that. But typically she will be slower to report that she feels like she's in love. So he's sitting there saying, you know, I'm in love and I'm going to be with her forever. And if I'm going to be with her forever, there's certain things that we might be interested in. And she's saying, I just met him five minutes ago, I mean what is this about?

**AUDIENCE:** [LAUGHTER]

**PROFESSOR:** Anyway. The result is some sort of a variable ratio schedule of reinforcement. And in most cases this works itself out just fine. But suppose the relationship doesn't go particularly well. Suppose for example -- well where's my extinction curve? Here's a good extension curve. So you're up here somewhere on this variable variable ratio schedule of reinforcement. And let's say she decides that this is not a relationship that she's interested in anymore. It takes him now an extremely long time potentially to get the hint and stop, you know, pressing that key in the Skinner box. And we'll talk later about the ambiguous nature of communications in this regard. If he's not sure whether she is saying yes or no or whatever, you can end up in trouble. And this an example, you know, where these sort of rules of association learning suddenly become relevant in behavior that's much more complicated than whether or not you're pecking a response key in a Skinner box.

It's that kind of application, the possibility of going from these very simple behaviors to much more complicated, much more richer behaviors that drove what was the leading school of psychology in the first half the 20th century in the US, which was known as behaviorism. Which was the doctrine that basically said, look classical conditioning, operant conditioning, a couple other bits, those are the atoms of behavior. And we can build up the molecules and the rest of the organism out of those atoms. That's all we need. So I put this quote from John Watson who's the founder of American behaviorism on there, where he says, you know, we can write a psychology. Define it as the science of behavior. That was a move by itself right. No science of behavior and mental life, or no signs of human mental life or something. The science of behavior of observable behavior, never go back on our definition. Never use terms like consciousness, mental states, mind, content and so on. It can be done in terms of habit formation, habit integration, which are terms for this sort of association learning.

He is basically saying, that look if you're taking chemistry, and you go to the chemistry prof

and say, you know, these elements you've got here, they're nice elements. But I think I want another 16 kind of constructs to explain what's going on here. The chemistry professor's going to look at you and say, no sorry these are the elements. Everything can be built out this stuff. You don't like it you got a problem. And the behaviorists were saying essentially the same thing about psychology. They thought that a very small set of atoms in this case, these Laws of Association, were the elementary properties, and you could build up everything out of that. That carried with it a couple of an interesting bits of ideology that will recur later in the course.

One of them was the idea that you were basically an association engine. You were there to learn associations. And that everything that was worth knowing in psychology, everything that was worth studying in psychology, was something that was learnable. That it was not interesting beyond, you know, for their purposes kind of trivial things. Like you came with eyes and not radar dishes. You know beyond that sort of thing, it was uninteresting what nature had provided to you. Psychology was the effect of what the interaction of the environment and these atoms of learning. That Everybody was essentially identical until this learning started. And what got you to MIT was the contingencies of reinforcement over the prior 18 years of your life.

This resonated with a certain democratic current in American political thought. In sort of, you know, grade school civics lessons form. This was the doctrine that anybody could grow up to be president. You didn't actually have to be a Bush to be president. Anybody could be president. What was important was how the environment shaped you. That's a doctrine in its strongest form known as empiricism. That look about right? OK. The opposite pole is nativism, the notion that your genetic innate endowment is determinative. And that you're here, because you were born with, you know, you've got the gene for calculus in there somewhere. Some of you may have now decided you lost it somewhere. But you had once upon a time.

So the notion here is what the behaviorist thought was they were strongly weighted towards this empiricist, environmentally driven side of things. In a couple of minutes. Why am I using the past tense? Why aren't we all behaviorists now? There are a number of reasons. I suppose the broadest reason is a course like this is full of, you know, on the one hand position on the other hand, you know. Empiricism and nativism. And I'll give you a hint for the exam. The answer always turns out to be both right. The extreme positions, the extreme theoretical positions in psychology never seem to quite work out. But sort of less trivially. The basics of association learning theory are absolutely worth a lecture in this course. And absolutely worth

chapter 4. And you'll find on the handouts, you know, guide for reading in chapter 4. But they're not all of psychology. Watson's statement says, you know, we can build a science of behavior without ever talking about, you know, consciousness for example. But, you know, that's an interesting topic.

And if I want to know about it, I don't want to be told by the field's ideologues that it's not a legitimate area of inquiry. I don't want to be told that the feeling aspect of emotion is not a legitimate topic of psychology. And that the only thing we can do is, you know, observe how many tears are coming out, something like that. It proved to be an incomplete psychology. In. The same way I should say, that the occupants of the nativist poll at the moment are the most dogmatic of the evolutionary psychologists. Evolution has wonderful explanatory power in psychology. But evolution is not itself a psychology. It's not a complete psychology by itself. It doesn't give you the richness of the field as a whole. Another important reason we're not all behaviorist is it turns out to be somewhere between uninteresting and wrong to argue that everything that was of interest was learnable. Language, we'll see later in the course, is an example. Course you learn the language that you speak. But you learned it because you had a brain that was built to learn a language. And that innate endowment, that language learning endowment, is worth study in its own right. And that wasn't something that fit into the behaviorist program. So that's why you're not a behaviorist now. But even if you're not a behaviorist, you still want to read chapter 4.