Action Learning

"What we have to learn to do, we learn by doing."
Aristotle (384-322 BC)

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Action learning is the process that results in the acquisition and improvement of skills.

Content

- Motor programs
  - Forward and backward models
- Perception / action similarities
- Principles of actions
- Learning to do
  - Control binons
    - Action and Expectation binons

This presentation describes how all the properties of a growing and integrated binon network performing temporal recognition can be used to learn action habits.

It starts with motor programs and motor control theory.

It then points out the numerous similarities between perception and action.

The principles of actions covers the subjects of:

The three stages of action learning - babbling, practicing, and automaticity

Covert versus overt actions and

Action devices and responses

And in learning to do I deal with a the action and expectation control binons.

I have a simple version of these working in Morse code recognition and a simulated robot in a maze.

Motor Programs

- Represented as action habits that
  - Are triggered by a stimulus
  - Perform a response
  - Expect feedback stimulus
- Combined in sequences
  - Feedback stimulus trigger the next response
- Reused in more complex actions
- Performed in parallel

In psychology and cognitive science the idea of a motor program is what I call an action habit.

Action habits are things that we do and observe others doing.

Action habits are complex and consist of many muscles being moved in parallel at any given time.

Motor Control

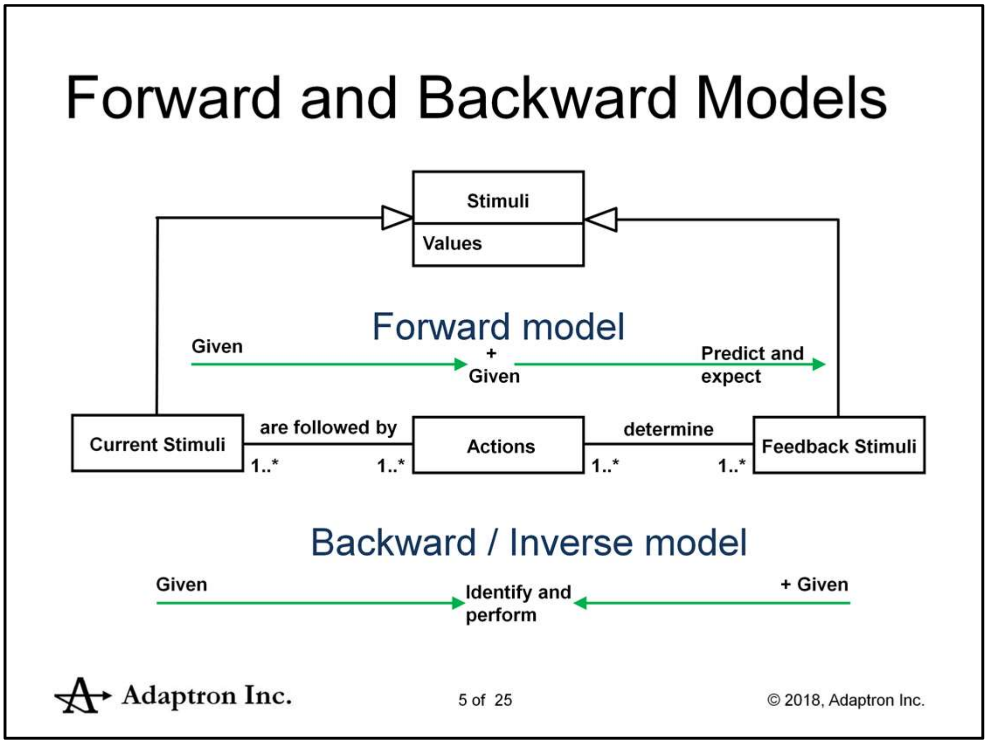
- Motor programs for motor control [1] [2]
- Forward model
  - Given the current stimuli and an action to perform you can predict the feedback stimuli to expect
- Backward / Inverse model
  - Given the current stimuli and the desired feedback stimuli you can identify the action to perform

When the motor program or action habit is performed the result is control of motion.

Current theories of motor control include Forward and Backward or Inverse models.

These theories often use the word state instead of stimuli.

I use the word stimuli because states results from the recognition of stimuli.



This UML Class diagram summarizes these two models.

The challenge arises because of the multiplicity.

Given one current stimulus there are many actions that can be done. The Inverse model can use the feedback stimuli to help choose the best one.

But when an action is done, many feedback stimuli can occur and they can be independent of the current stimulus before the action was performed.

This needs to be analysed at a simpler level.

Perception / Action Similarities

- Hierarchical [3]
- Learning is bottom up
- Reuse of simpler patterns ~ Simpler skills
- Intrinsic motivation
- Senses ~ Action device types
- Sensors ~ Action devices
- Stimuli ~ Responses

Look at the similarities between perception and action.

Both pattern recognition and action habits take the form of a tree or hierarchy. [5]

The trees grow bottom up because we need to learn the simpler patterns and simpler actions first.

Patients that have muscle and limb damage know all about the process of having to relearn their action habits as they have gone through physiotherapy.

Action habits form a tree structure in which more complicated actions are combinations of simpler actions.

Less complicated actions get reused just like simpler patterns are reused to recognize more complicated ones.

Central Pattern Generators are usually controlled by multiple command neurons.

[see Motor Pattern Generation by Jeffrey Dean and Holk Cruse in Handbook in [5]]

Both recognition and action habits can be learnt using intrinsic motivation.

Children don't need pleasant (rewarding) or unpleasant (punishing) feedback to learn how to perform new skills.

New ones are remembered because they are novel and interesting.

The senses correspond to types of action devices and sensors correspond to action devices.

Stimuli are input signals whereas responses are output signals. Both involve a measurement value.

Also read Sensorimotor Interactions and Central Pattern Generators by Avis H. Cohen and David L. Boothe in handbook [5]

Perception / Action Similarities

- Automaticity of learnt habits
  - Recognition
  - Action
- Visual & verbal imagery ~ Motor imagery [4]
- Repetitive patterns ~ repetitive actions
- Perceptual set [5] ~ Preparatory (motor) set

Both recognition and performing actions can be done automatically after practice and learning.

Both perception and action can be imagined.

Patterns repeat in perception and we perform repetitive actions such as in walking.

A perceptual set, also called perceptual expectancy, is a predisposition to perceive things in a certain way.

But it is also an expectation specifying the occurrence of a forthcoming action with a proper timing and order.

Three Stages of Action Learning

- Babbling
  - Random actions
  - Reflexive actions
- Practicing
  - Combining actions
  - Repeating them until familiar / learnt
- Automaticity
  - Started consciously
  - Performed subconsciously

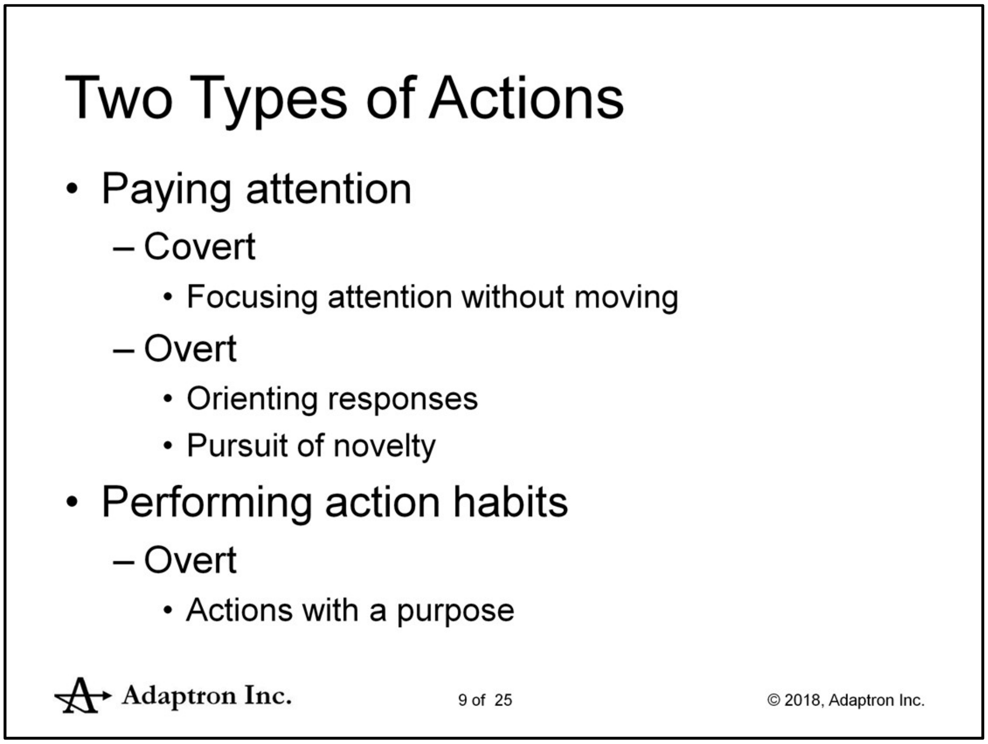
There are three stages in learning to perform actions.

Babbling creates random actions that we pay attention to.

The actions that produce interesting (novel) outcomes (feedback stimuli) are practiced until they are learnt.

This includes combining already learnt ones.

Then learnt action habits are performed automatically and subconsciously but must be started consciously.



There are two types of actions, paying attention and movements.

A key concept here is that paying attention is something we do. It’s a type of action.

We do it in order to perceive and recognize things.

We can shift our focus of attention without moving.

But if we do move then you have an orienting response. Its reflexive initially, caused by things that attract our attention.

Then we learn to do it in the pursuit of novelty and eventually it becomes automatic.

And then movements are observable motor actions that we normal think of as action habits, usually to accomplish some goal.

Covert versus Overt Actions

- Covert actions
  - Focusing, setting, priming attention
    - Activating recognition habits
  - Thinking
- Overt actions
  - Motor actions
  - Enabling, potentiating[6] action
    - Activating action habits

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Actions can be covert (not observable) or overt (observable by others).

Focusing attention is mostly covert. And thinking is covert while motor actions are overt.

Different authors use other word for focusing attention.

Stephen Grossberg also uses the words Sensitizing, Modulating, and Activating instead of focusing, setting or priming.

Common word for the same concept for motor actions are Enabling and Potentiating. Randy Gallistel uses the word potentiating.

I like to use the word Activating for both types of action.

Thinking is covered in more detail in the Thinking presentation.

Principles of Action

- Reinforcement learning based on novelty[7]
  - Motivates
    - Focusing of attention
    - Orienting response
    - Motor actions
- Uses the where information
  - Configuration tree

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In artificial intelligence and machine learning the subject of reinforcement learning is all about learning action habits that achieve some kind of reward.

Rather than use pleasant and unpleasant feedback stimuli which is extrinsic motivation I use intrinsic motivation.

That is the pursuit of novelty and avoidance of familiarity. This results in curiosity and exploratory behaviour.

Since the same type of action can be performed on multiple action devices the what is independent of the where.

This is where the configuration tree of senses, sensors and action devices is used.

So an action habit combines the What and the Where.

Principles of Action

- Builds on successful random actions
  - Motor babbling
    - Trial and error learning
  - Orienting responses
  - Reflexes
- Reuse of simple learnt tasks
  - Combined to perform complex tasks
  - Learns bottom up

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The babbling stage of action learning is obvious in the behaviour of babies. They do both motor and speech babbling.

It is effectively trial and error learning. And orienting responses and reflexive actions are also sources of unintentional motions that we learn from.

We keep the actions that are interesting and repeat them intentionally in similar situations.

And once we have learnt them we combine them in parallel and series to perform more complex tasks.

This is a bottom up learning process.

Action Devices & Responses

- Multiple types of devices
  - Motors, Speakers
- Multiple devices per type
  - Many motors
- Magnitude values
  - Rotate x degrees clockwise
- Symbolic values
  - Move to location x

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Robots can be built with all manner of action devices like motors, speakers and lights whereas we only have muscles.

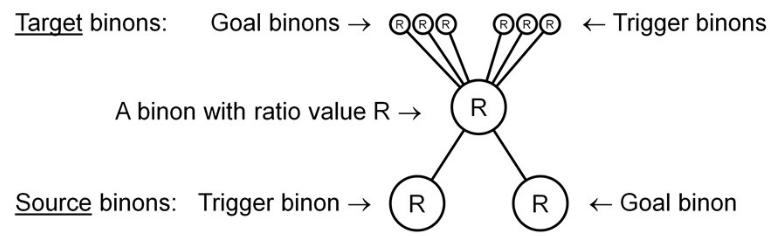
But just like for each sense one has many sensors, for types of action devices one can have many devices.

When controlling an action device it is best to think of it as simple as possible and all the responses it is given are change amounts rather than specific desired results. This means it does not have to monitor itself to detect when it has reached that result.

However, one can have action devices that are given symbolic responses.

The Binon structure

- Two types
  - Spatial and Temporal



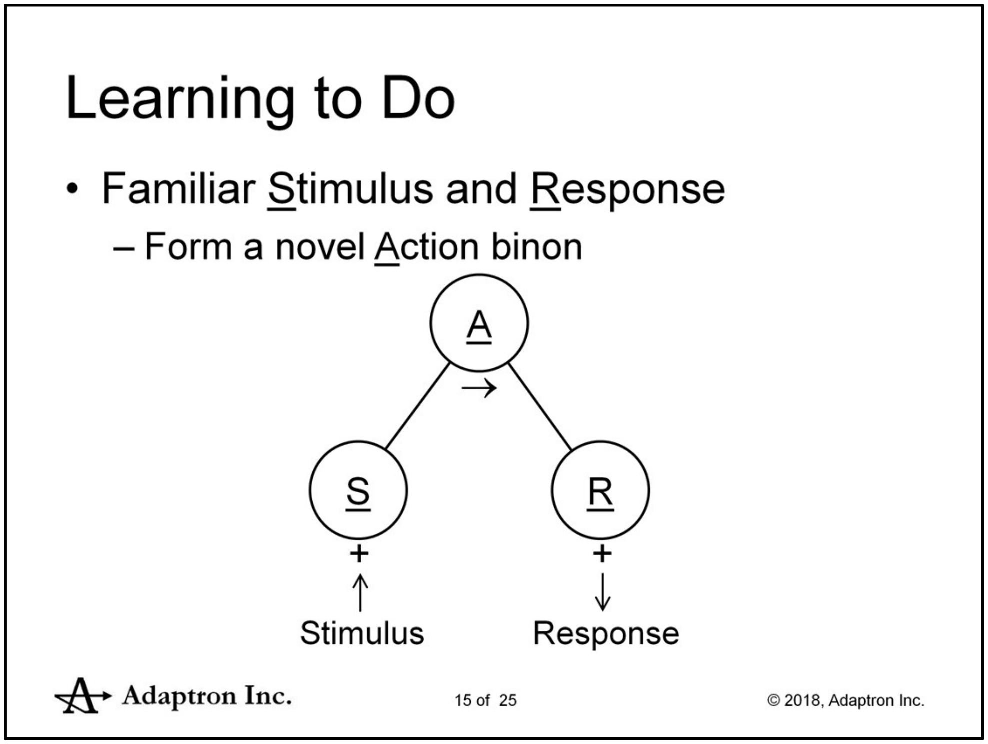
Just a quick refresher about the binon structure.

And binons represent what things are. They have no knowledge of and are independent of where they occur.

The where information is in the nodes of the configuration tree.

For spatial and temporal recognition purposes stimulation signals came in from the source binons.

On the next slides you are going to need to think of some different stimulation patterns



This and the following slides are my current designs for action habits. It is an integrated recognition & action neural network of binons.

In previous presentations I have only described spatial and temporal recognition binons. On these diagrams they are all labeled as Stimulus binons.

And now I am introducing a Response binon. It behaves or functions in the opposite direction from recognition. Any one of the goal target binons of a response binon can stimulate it. And then the response binon stimulates its two source binons. And there are spatial and temporal versions of Response binons.

The responses can be orienting responses. The goal of an orienting response is always to obtain novel information (intrinsic motivation). The response does not need to obtain a pleasant result (extrinsic motivation). Response binons are just like class binons for recognition and are composed of contrast, quantity/repetition, shape/duration and separation patterns. Also, responses can do no action at all. They can be "do nothing" responses.

Just as stimuli can simultaneously come from multiple senses and sensors, responses are sent in parallel to a particular configuration of action devices.

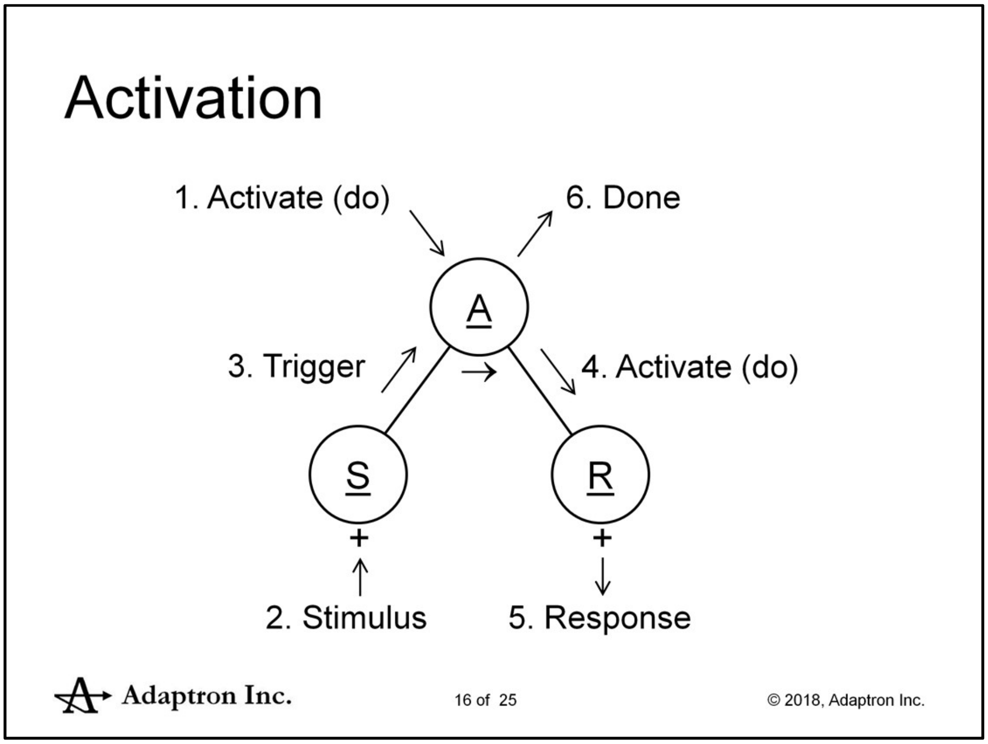
The Action binon's behaviour is different. It is stimulated by its trigger source binon (the Stimulus binon) and it then stimulates its goal source binon (the Response binon).

So what is happening here is once a stimulus has been recognized the response binon is activated to perform the response. This is the first half of the backward/inverse model mentioned earlier. That is, given a stimulus you can identify and perform the action. This is where thinking needs to be done in order to choose the correct action. If you know artificial intelligence then Action binons are equivalent to production rules in production systems.

For learning purposes, when a familiar stimulus occurs and Adaptron has nothing interesting to do, it produces a random familiar response (babbling). Then a novel Action habit / binon is created to associate the Stimulus and Response. This is like the concept of "fire together, wire together". The response happens right after the stimulus and they get associated together because of coincidence by the new action binon.

The next time the stimulus occurs Adaptron will perform the novel action binon (do the response) to practice it so it becomes familiar and learnt.

The Action binon is equivalent to the concept of a command neuron in neuroethology, which is the science of the neurobiological fundamentals of behavior. Neuroethology contributes to neuroscience.



This interaction diagram captures the order in which the process takes place.

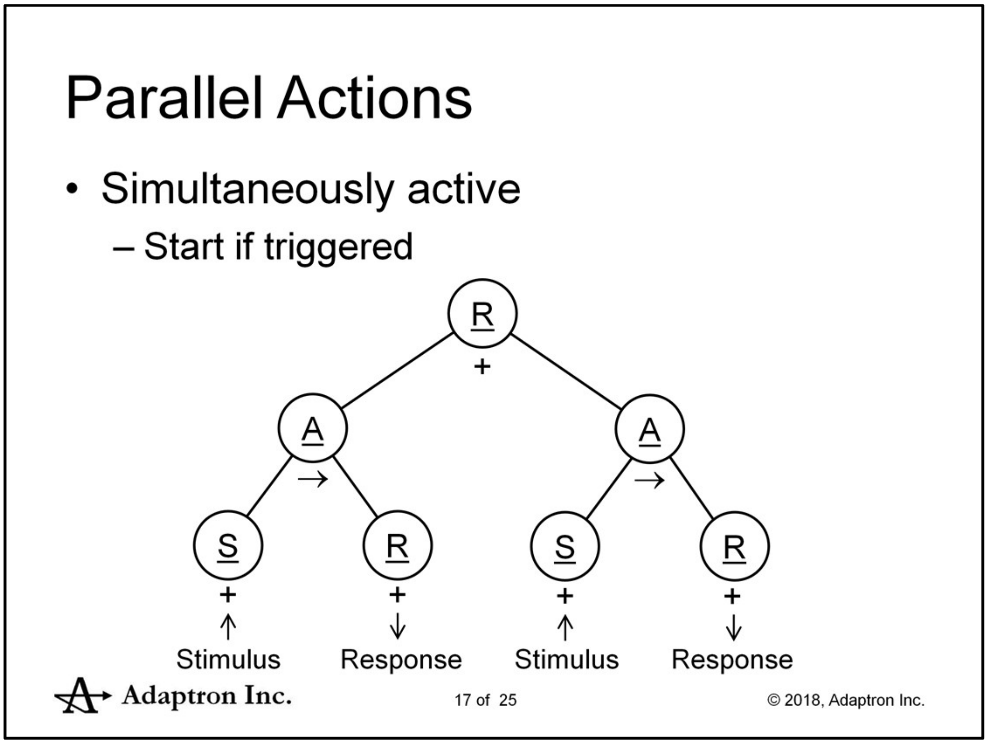
The initial activation originates from a decision in the thinking process which is described in the Thinking presentation.

The action binon is active but needs to be triggered by its trigger binon, the stimulus binon.

The stimulus is recognized the action binon is triggered. It now activates the response which gets done and the

Action binon notifies all it trigger targets that it is done. Trigger targets will have to be activated if they are to do anything as a result.

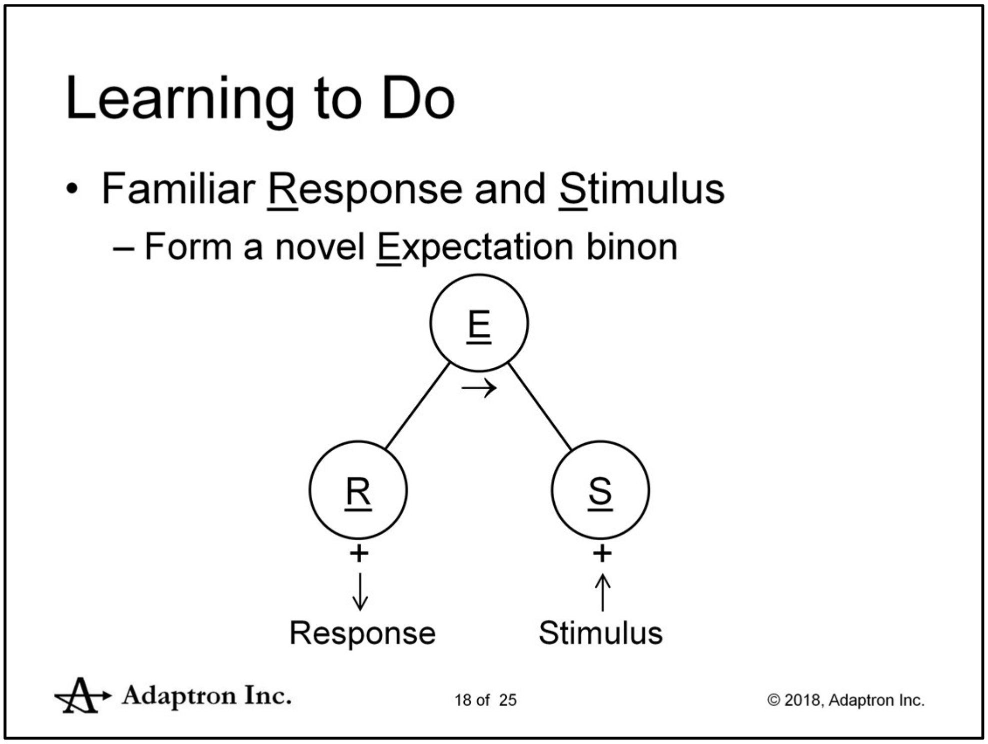
If there are no activated trigger targets then the action habit is finished. Notice how the wave of activation flows from left to right.



Sometimes we want to activate several tasks at the same time but only have them start working when they recognize their trigger stimulus.

For example, consider the task of walking from one room to another. The normal action habit is to repetitively move one leg after the other. But the task must be ready to perform the open door task if the door is shut, or to walk around an obstacle if one is encountered.

The design is to have a spatial response binon activate two or more action habits. Each will be waiting for its stimulus trigger source to be recognized before starting.



Focusing attention is also an action, it is something we do.

In this design once the Response binon has been performed it notifies all its Expectation binons that it is done. And the Expectation binon activates its goal source binon, the Stimulus binon, to pay attention.

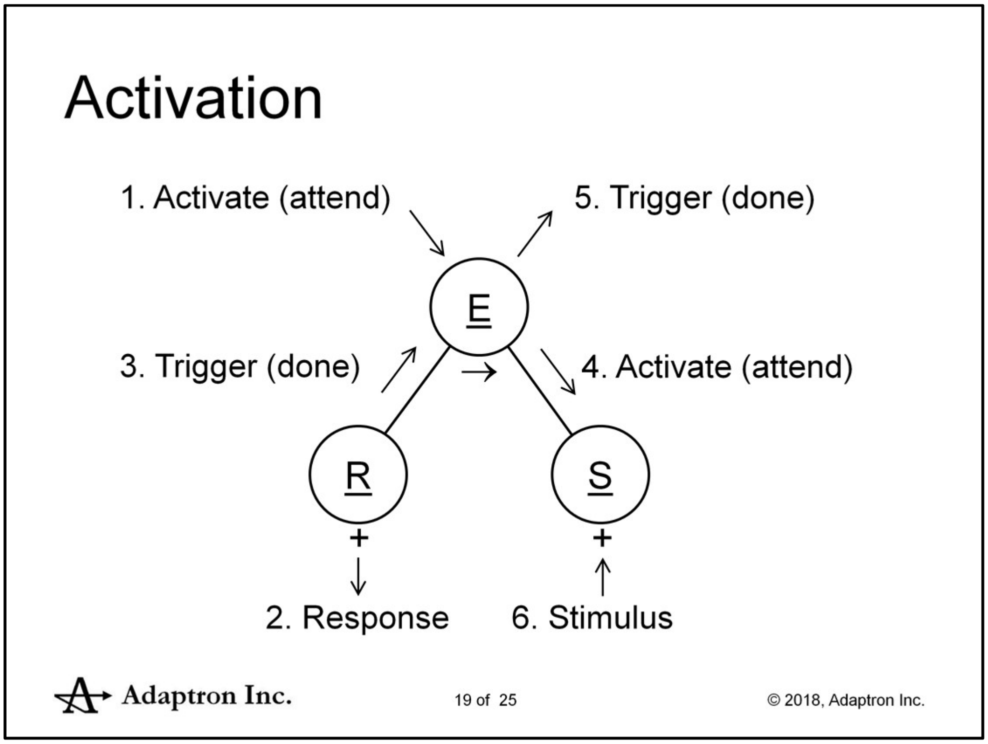
So a stimulus binon behaves slightly differently from how it was described in previous presentations. Here it must be activated before it will recognize the pattern from its two source binons. Then once the pattern it recognizes it stimulates all its trigger target binons. These are the action binons on the previous slides.

So what is happening here is once a response has been produced the stimulus pattern recognition binon is activated to pay attention to the expected stimulus result. This is the second half of the forward model mentioned earlier. That is, given a response you can predict and expect the feedback stimulus.

For learning purposes, when a familiar Response is done, attention will be attracted to the resulting Stimulus. If the stimulus is familiar a novel Expectation habit / binon is created to associate the response and stimulus. You could think of the response binon creating a done signal that stimulates its trigger target binon, the expectation binon.

The next time the response is done it will want to focus attention on the expected stimulus to determine that it is a valid expectation habit. This is based on intrinsic motivation because the expectation binon is novel and needs to be practiced.

Note that during learning the stimulus attracts attention but during practice attention is focused. The attraction of attention is synonymous with babbling while performing attention is synonymous with doing something.



This interaction diagram captures the order in which the process takes place.

The initial activation to focus attention originates from a decision in the thinking process which is described in the Thinking presentation.

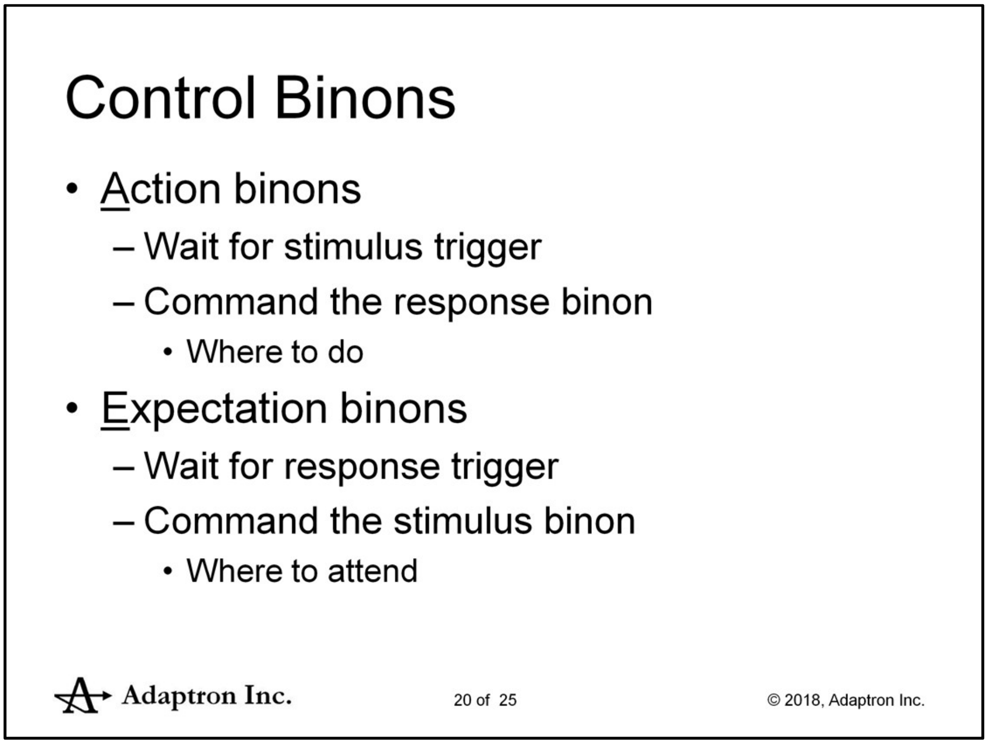
The expectation binon is active but needs to be triggered by its trigger binon, the response binon saying it has finished doing what it was asked to do by the previous action binon.

The response is done the expectation binon is triggered. It now activates the stimulus binon to attend to the expected result.

Without waiting for the stimulus binon to recognize its pattern the expectation binon notifies all it trigger targets that it is done.

Trigger targets will have to be activated if they are to do anything as a result.

If there are no activated trigger targets then the expectation habit is finished. Again, notice how the wave of activation flows from left to right.



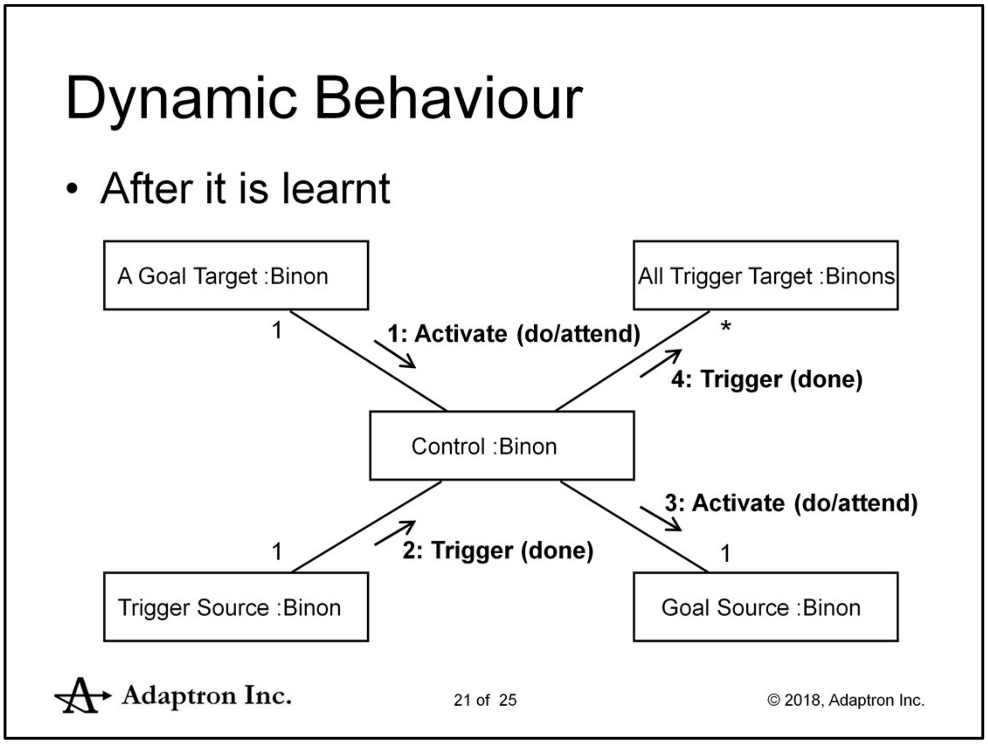
Action binons and expectation binons are both control binons. They are equivalent to command neurons in neuroscience.

What they have in common is that they both wait for their trigger source binon and they then command their goal source binon to perform.

But they also need to identify the configuration requirements. That is, they need to specify where to do or attend.

How much to do or expect (strength and intensity) and how long to act or perceive (speed and duration) is the activation tree information.

It must be passed down with the activation commands as the action habit is being performed.



This a UML communication diagram to illustrate how the wave of activation travels horizontally from left to right through the previous hierarchies.

The dynamic control flow is the same for both control binons. It’s like turning the normal spatial recognition dynamic behaviour on its side. Rather than flowing up the tree it flows in time order from left to right.

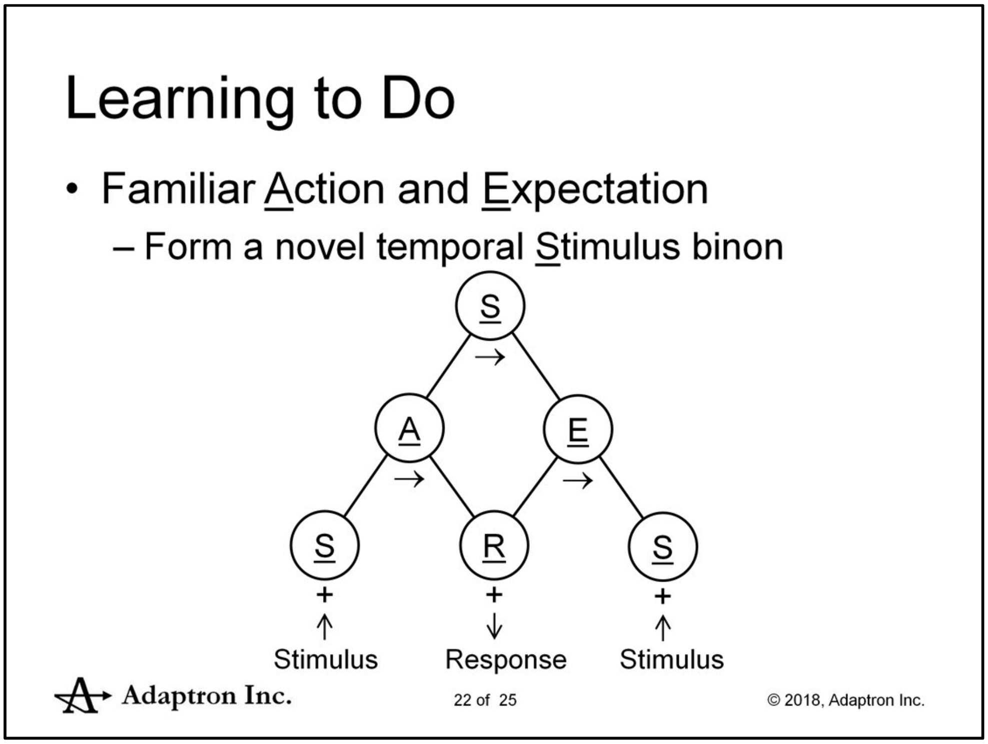
1: Goal Target binons activate the process.

2: The action or expectation control binon waits for the trigger source binon to fire or say it is done.

3: The goal source binon is activated and then

4: the trigger target binons are notified that the action has been done.

The attend activation is the same concept as perceptual set. And the do activation is the same concept as preparatory motor set.

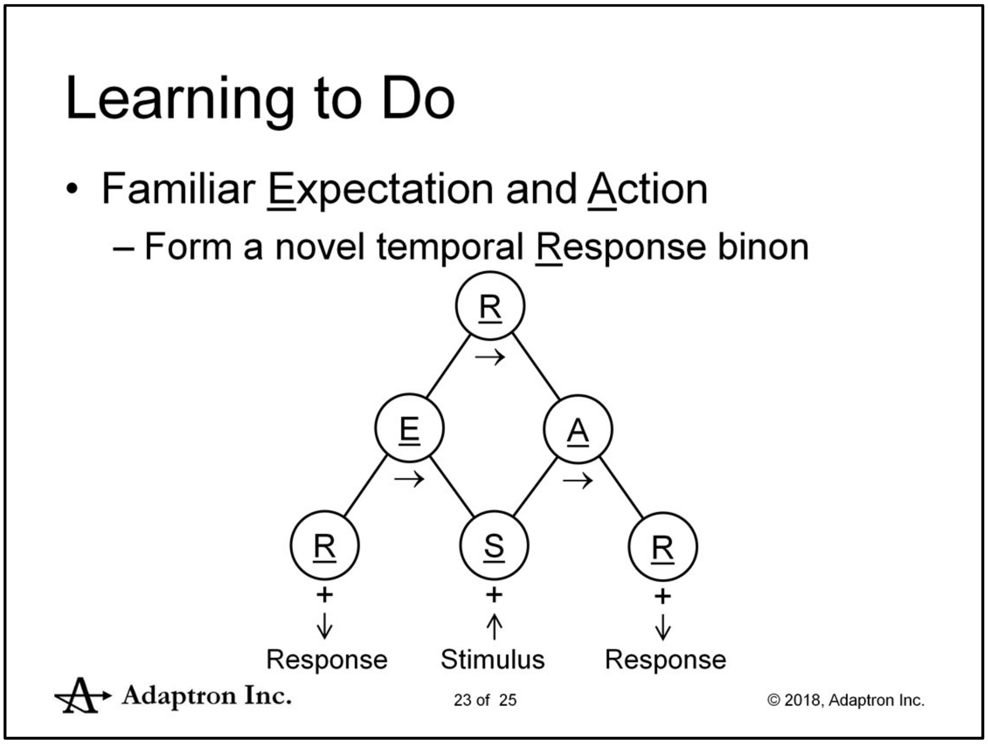


Once the Action and Expectation are both familiar and the complete sequence is performed a novel temporal Stimulus binon can be created.

This binon represents the fact that given the first stimulus you can expect the last stimulus if the response is done. This is the forward model previously described.

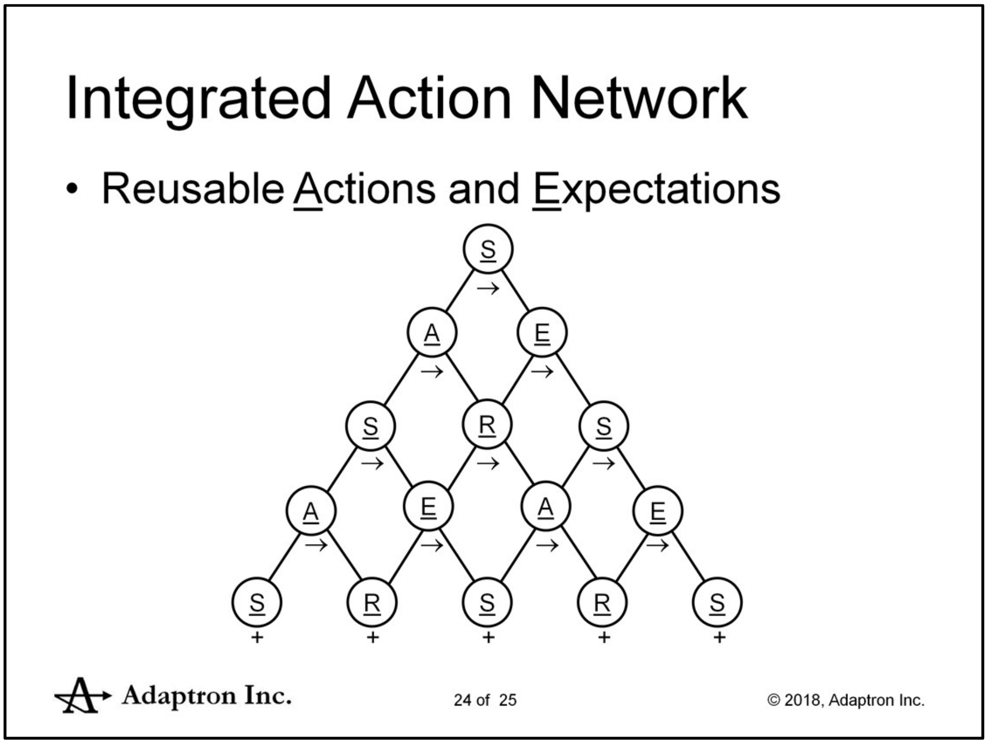
It can also be used as the backward / inverse model, given the 1st stimulus if you want the last stimulus then perform the response.

If the response binon is a “do nothing” response then the temporal stimulus binon is the temporal recognition binon from the previous presentation on Temporal Recognition.



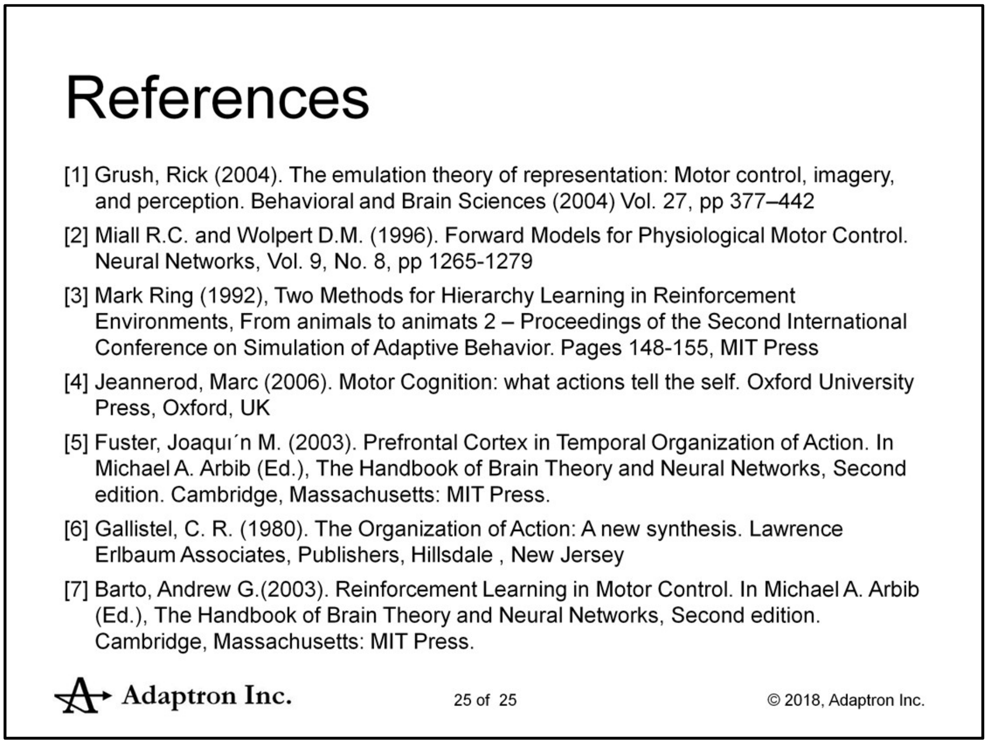
Once the Expectation and Action are both familiar and the complete sequence is performed a novel temporal Response binon can be created.

This binon now represents a more complex temporal response that can be reused in more complex tasks. It is available for babbling purposes.



The result is an integrated recognition & action network in which lower level action, expectation, temporal stimulus and temporal response binons can be reused to form higher level behaviour.

But how does it get started? That is where thinking comes in. A one step look ahead uses the network to determine if the action or expectation binon is worth doing. For intrinsic motivation this is driven by the binon being novel and therefore worth practicing / repeating. If it is familiar then a two or more step look ahead will search out something worth doing. If thinking that much ahead has not been learnt and nothing was found worth doing then babbling will be done.



These are all good documents worth reading.