Thinking

"… thinking is identical with the thoughts which are its parts"
Aristotle in his de Anima (On the Soul)

"Everything you can imagine is real"
Pablo Picasso

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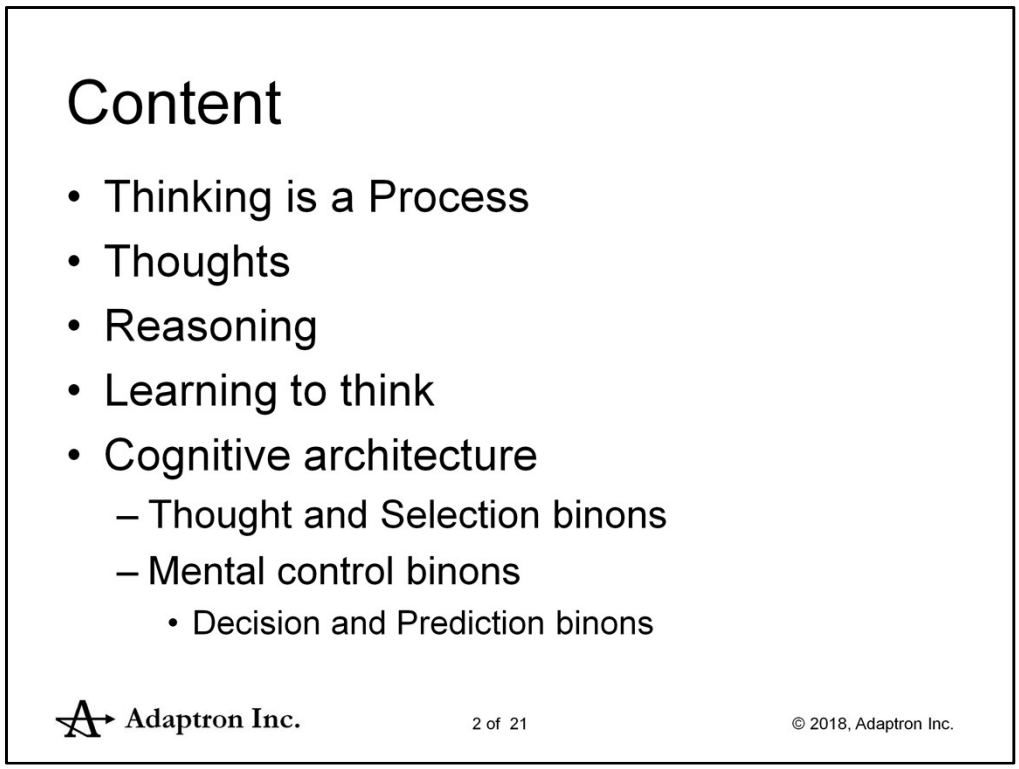
Thinking is the process that we use to model reality by recalling past experiences as thoughts.
We think in order to solve problems and decide on what actions to perform.



This presentation describes how a separate thinking binon network is used for the recollection of experiences, which produce thoughts, how decisions are made and how mental babbling is used in learning to think.
First, thinking is a process.

- Thoughts
    - Recalled past experiences
    - Process feedback - feelings
- Reasoning
    - Searching experiences (recall) - motivated
        - For planning, problem solving & deductions
    - Decisions to Start acting and perceiving
- Learning to think
    - Mental babbling
    - Thinking or practicing actions
- Cognitive architecture
    - Thought and Selection binons
    - Mental control binons – Decision and Prediction

Thinking is a Process

- Models reality
  - Recalling past experiences
    - Produces thoughts / ideas
- Triggered by a stimulus
  - Interrupted by an unexpected stimulus
- Decides to perform
  - Actions
  - Perception
  - Recollection

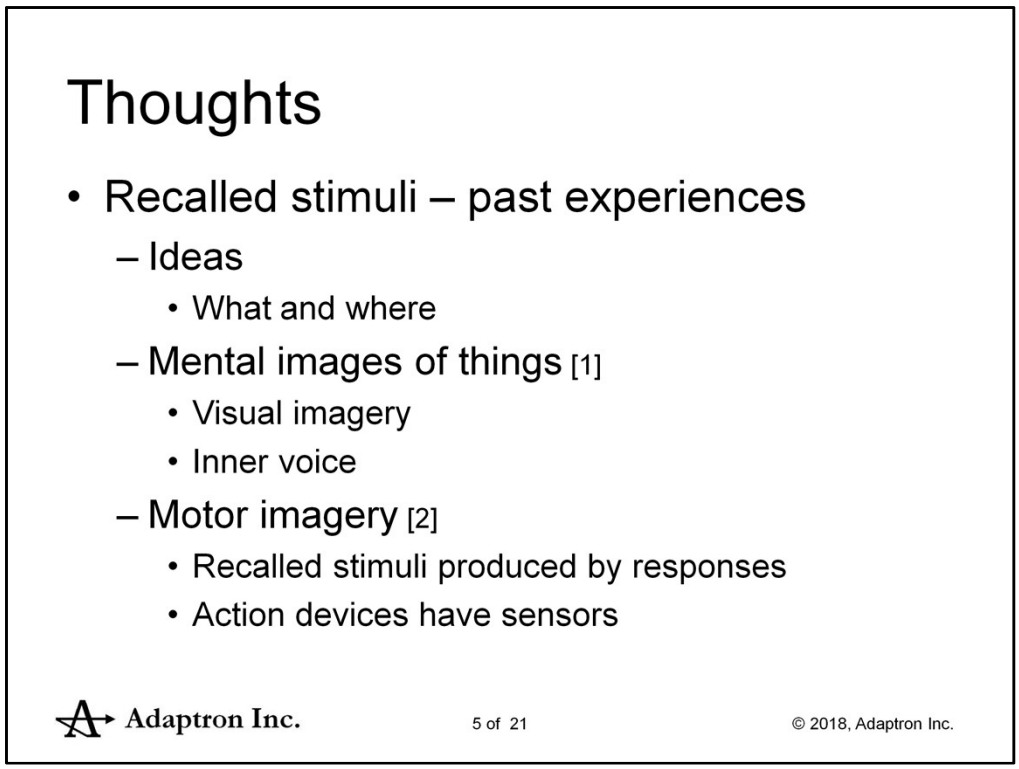
Adaptron needs to think. It needs to use its past experiences as its model of reality.

It uses this model to mentally simulate the possible consequences of its actions before doing them.

Thinking is a Process

- Search of past experiences
  - One or more look ahead steps
    - Train of thoughts / ideas
  - Motivated to
    - Obtain reward or novelty
    - Avoid punishment and familiarity

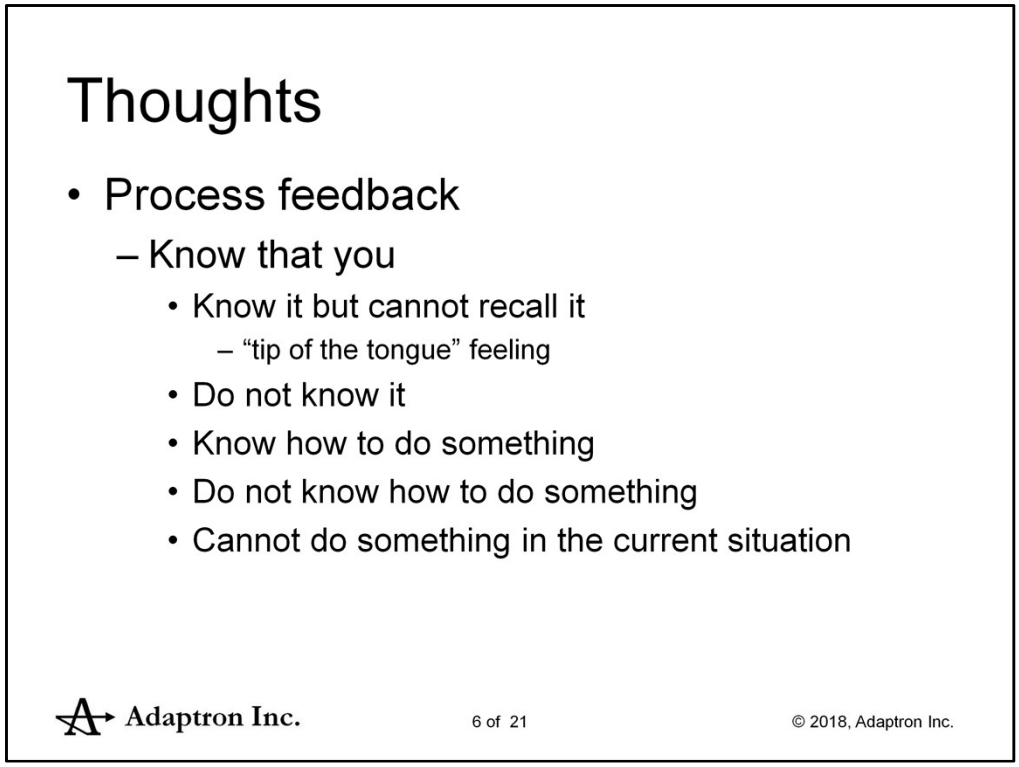
Between the trigger and the decision we search our past experiences.



Recall produces thoughts.

In motor imagery you do not recall your responses. Instead you recall the stimuli caused by your actions.

This is possible because every muscle has internal senses that tell you what they are doing



But thinking’s stimuli are not just remembered experiences. They also include stimuli that represent how well the thinking process is working.

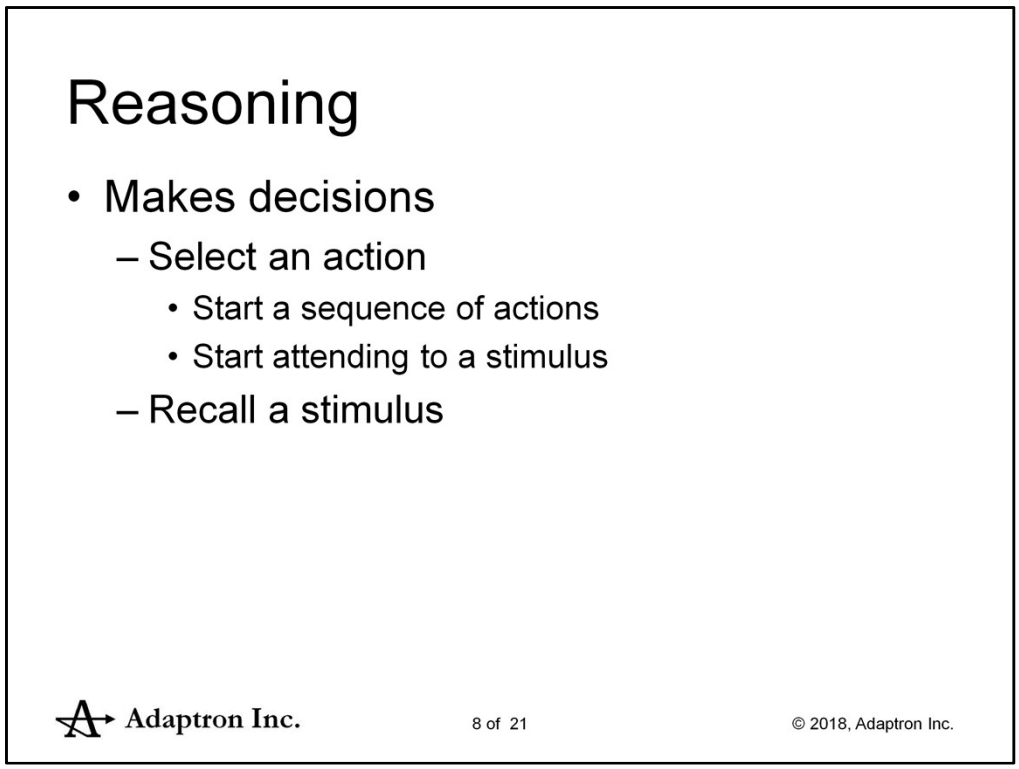
That’s because recall can fail.

They include information such as “I know I knew it but I can’t remember it”, “It’s on the tip of my tongue” and “I know I don’t know that”.

Reasoning

- Mental simulation
  - Recalling past experiences
  - Prediction of consequences
    - Planning
    - Problem solving
- Sequence of inferences / thoughts
  - Deduction
  - Imagination

What we do with these recalled thoughts



Once an action is thought about that will result in a desired stimulus the decision is then made to perform that action.

After performing a deduction you might start to express it verbally.

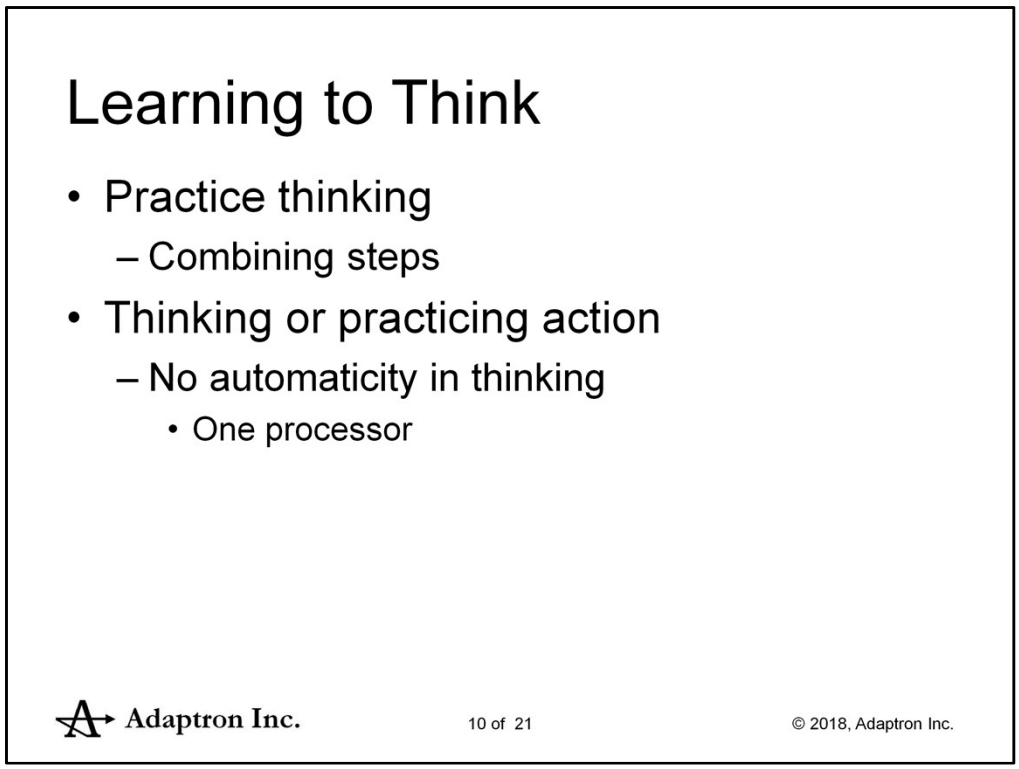
After thinking of a plan you may start to implement it.

After recalling one idea you may recall an associated one.

Learning to Think

- Remember mental functions
  - To learn and repeat them
- Mental babbling
  - Unexpected stimulus attracts attention
  - Reflexive one step look ahead
    - Forward model
    - Given a current stimulus is there an action I can perform to obtain a rewarding feedback stimulus?

Thinking starts with mental babbling, just like recognition and action learning.



We learn more powerful reasoning skills by combining simpler ones that we learn at a younger age.

But there is a limitation. We only have one processor. We can only be conscious of one thing at a time.

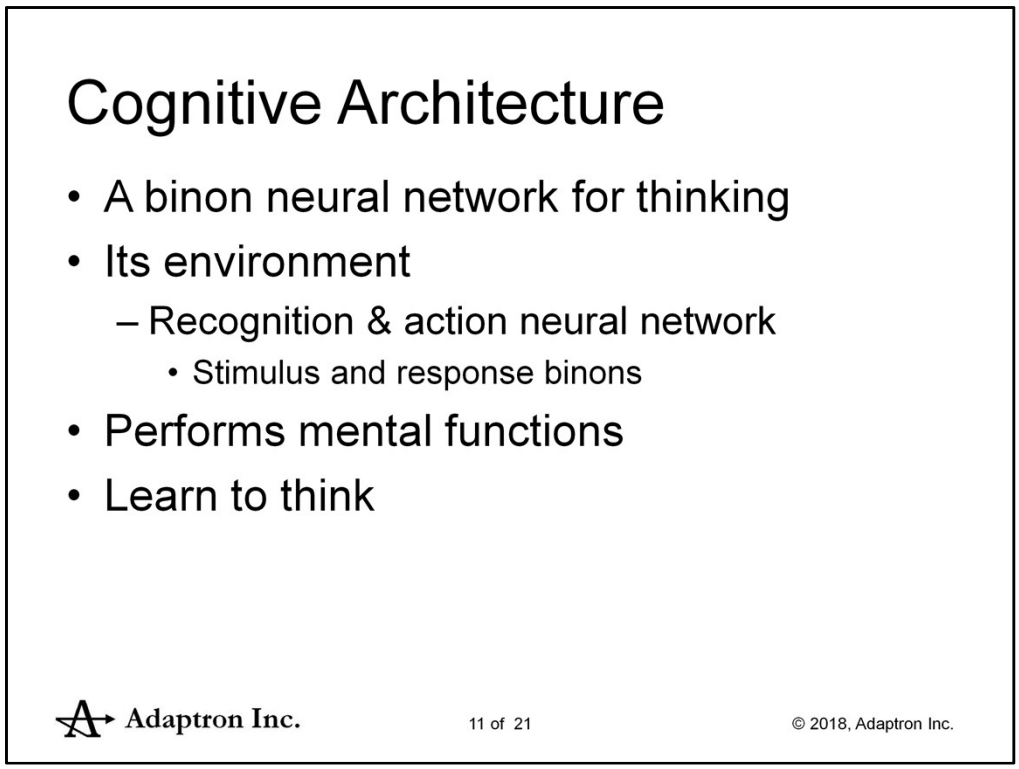
And therefore we are either thinking while our actions are being done automatically or we are conscious of

the actions being done – they are being practiced.

After a decision is made to act the action is begun. Depending on how well practiced / learnt the action is, it will

be performed in automatic mode or practice mode. In automatic mode we can go back to thinking.

In practice mode we must concentrate on performing the action.



The hierarchical ANN of stimulus and response binons representing ones experiences is the environment for thinking.

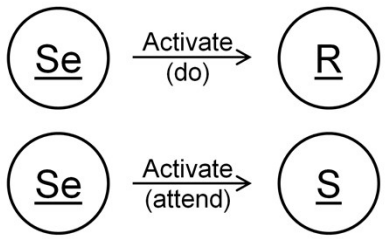
It is the source of thinking's stimuli (ideas or thoughts). And thinking's actions are the focusing of attention on these binons.

These actions result in the traversal of the network. Up the tree for more specific things, down the tree for more general concepts and across the tree for what to expect next.

But rather than pre-program its thinking processes Adaptron must learn them.

Mental Functions

- Selections activate
  - Response binons
    - Perform a response
  - Stimulus binons
    - Attend to a stimulus



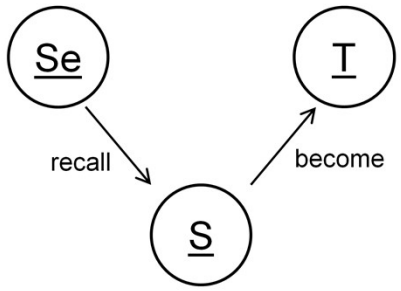
Two kinds of mental functions.

1/ The ones that activate a stimulus or response binon to start doing them.

2/ The ones that recall a stimulus binon as a thought.

Mental Functions

- Selections recall stimuli
  - Relative to previous selected stimulus



Recall always retrieves a thought based on the previous one.

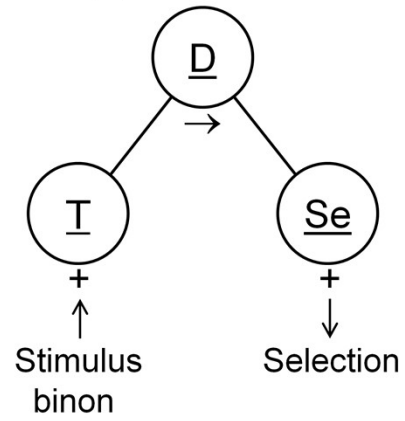
Recall Mental Functions

- Next stimulus
- Source stimulus
  - Given a toy as a stimulus
  - What is the shape of the toy?
- Target stimulus
  - Given toys as the stimulus
  - What is an example?

Recall mental functions navigate the stimulus binon network. They result in thoughts.

Learning to Think [3]

- Familiar Thought and Selection
  - Form a novel Decision binon



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When the familiar thought occurs and there is nothing interesting to do, it produces a random selects a possible mental action (babbling).

A novel Decision habit / binon is formed to associate the Thought and Selection. The selection does not stimulate the decision binon.

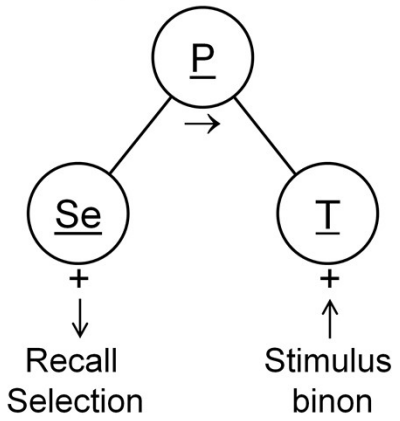
It is more like the concept of “fire together, wire together”. The selection happens right after the thought and thereby gets associated with due to coincidence.

The next time the thought occurs it will perform the novel selection binon (do the mental action) to determine that it is a valid decision habit.

Mental actions can be recollection of associated stimuli. And they can be to activate a stimulus or response binon.

Learning to Think

- Familiar recall Selection and Thought
  - Form a novel Prediction binon



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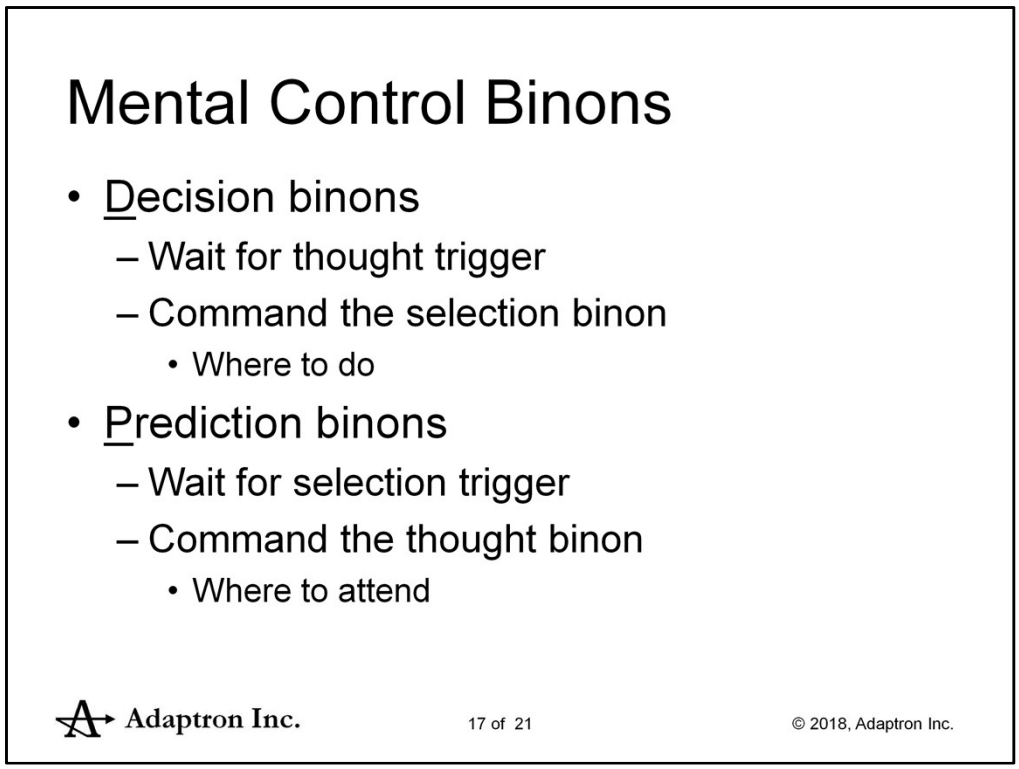
After we have selected a mental recall function we need to learn what thought to predict.

If the selected function is to activate a stimulus or response binon then no prediction binon is produced because the thinking has stopped. Practicing has begun. Our thinking is effectively taking place in short bursts. Triggered by a stimulus, a sequence of recalls and then a decision to select an action. If the action is automatic then we can return to thinking. Else we focus on the action.



Decision binons and Prediction binons are both mental control binons.

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.

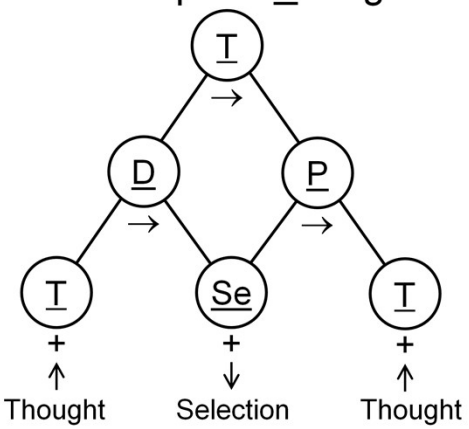
But they also need to identify the configuration requirements. That is, they need to specify where to do or attend.

This is the where in the perception and action binon network.

Listen to the Action Learning presentation to get a better idea of the dynamic behaviour. It's the same as the recognition and action binon network.

Learning to Think

- Familiar Decision and Prediction
  - Form a novel temporal Thought binon



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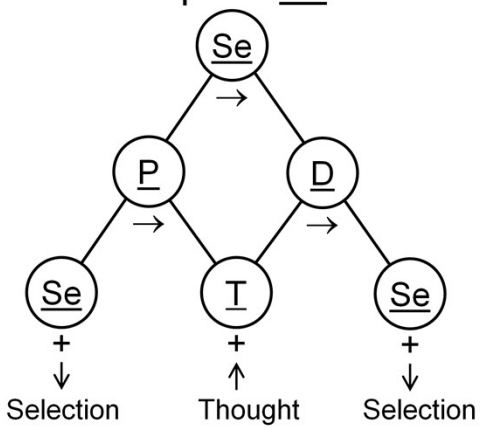
Once the Decision and Prediction are both familiar and the sequence is performed a novel temporal Thought binon can be formed.

This binon represents the fact that given the first thought you can predict the last thought if the selection is done.

Learning to Think

- Familiar Prediction and Decision
  - Form a novel temporal Selection binon



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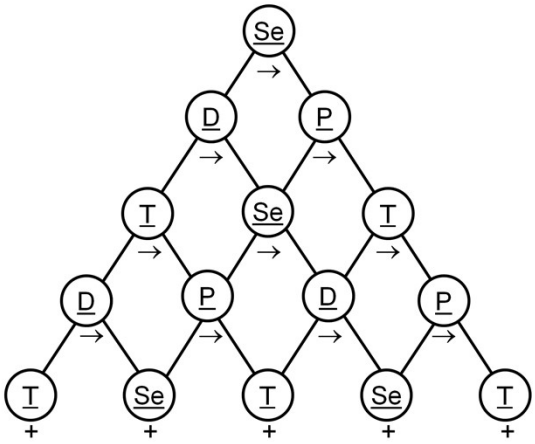
Once the Prediction and Decision are both familiar and the sequence is performed a novel temporal Selection binon can be formed.

This binon represents the fact that if you have selected one mental function and have got the predicted stimulus then you can select the second mental function.

Integrated Thinking Network

- Reusable Decisions and Predictions



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The result is an integrated thinking network in which lower level decision, prediction, temporal thought and selection binons can be reused to form more complex thinking.

References

[1] Knauff, Markus (2013). Space to reason: a spatial theory of human thought. MIT Press, Cambridge, Massachusetts.

[2] Jeannerod, Marc (2006). Motor Cognition: what actions tell the self. Oxford University Press, Oxford, UK

[3] Schmidhuber Jürgen (2015). On Learning to Think: Algorithmic Information Theory for Novel Combinations of Reinforcement Learning Controllers and Recurrent Neural World Models. Technical Report, arXiv:1210.0118 [cs.AI]