Xzistor Concept Brain Model

Simple Robot Explanation

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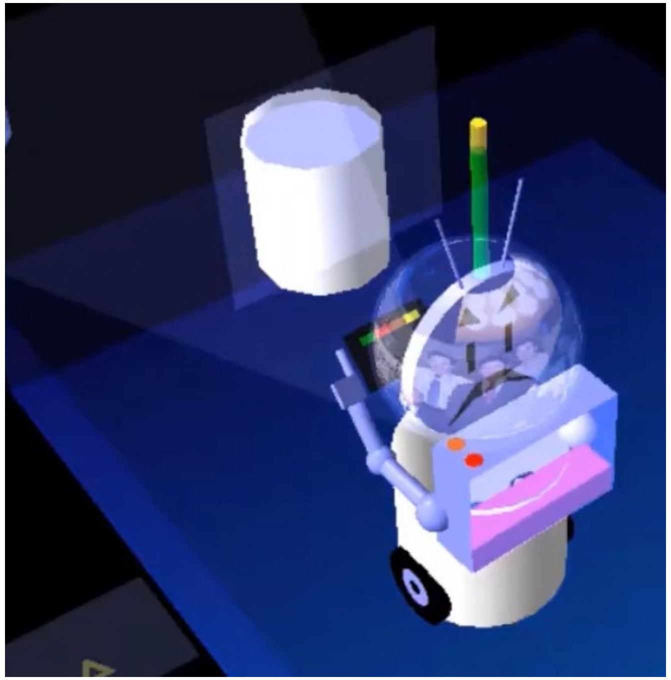
Assume robot has 1 utility parameter:

1.) Stomach Level (SL)

Stomach full, SL = 100 %
Stomach empty, SL = 0 %

Full stomach. Simulated on back of robot showing pink ‘power juice’.



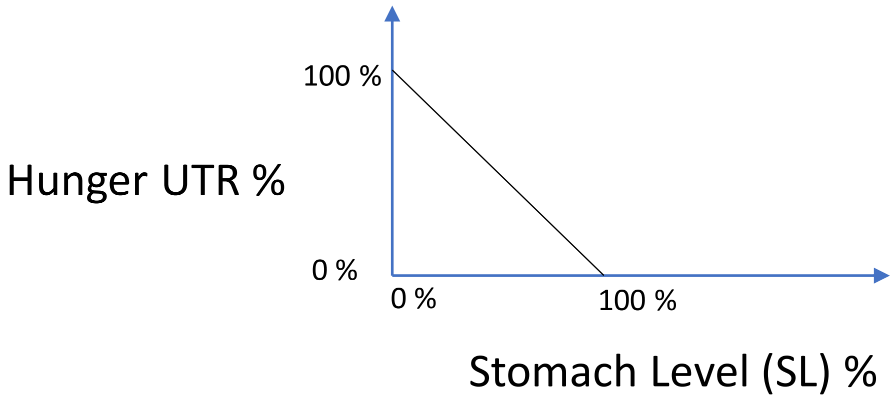
Empty stomach. Note frown on face. Also starting to cry.

Assume robot has 1 Hunger Urgency To Restore (UTR) Control Mechanism:

Hunger Urgency To Restore (UTR) level as a % = function of Stomach Level = f(SL)

If Stomach empty, SL = 0 % then Hunger UTR = 100%
If Stomach full, SL = 100 % the Hunger UTR = 0%

UTR (%) = f(SL) = (-1 x SL) + 100   where 0 < SL < 100

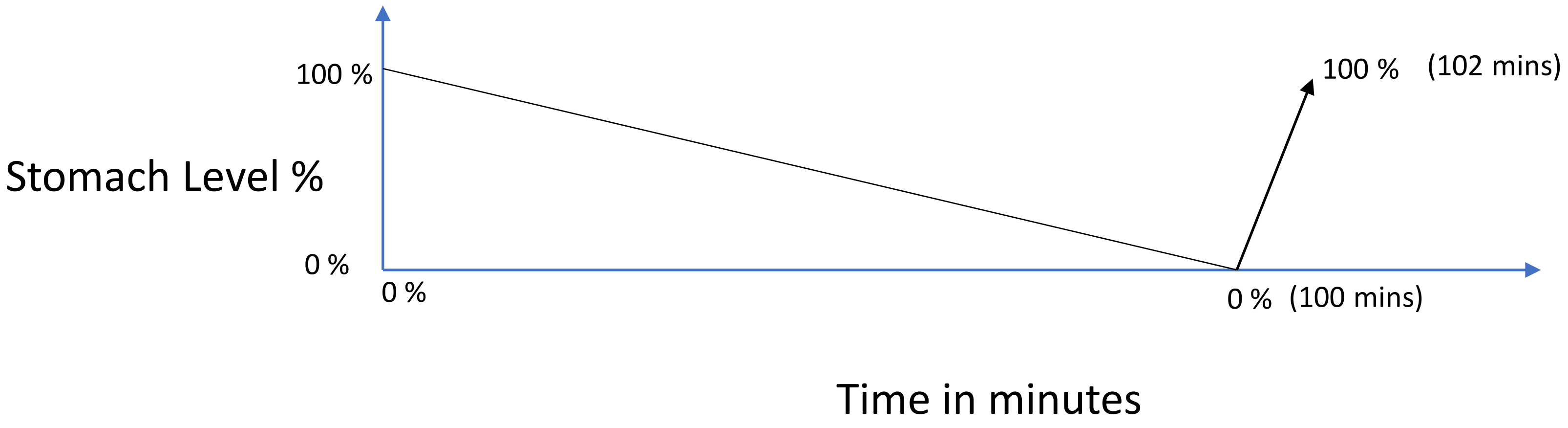


Consider a case where:

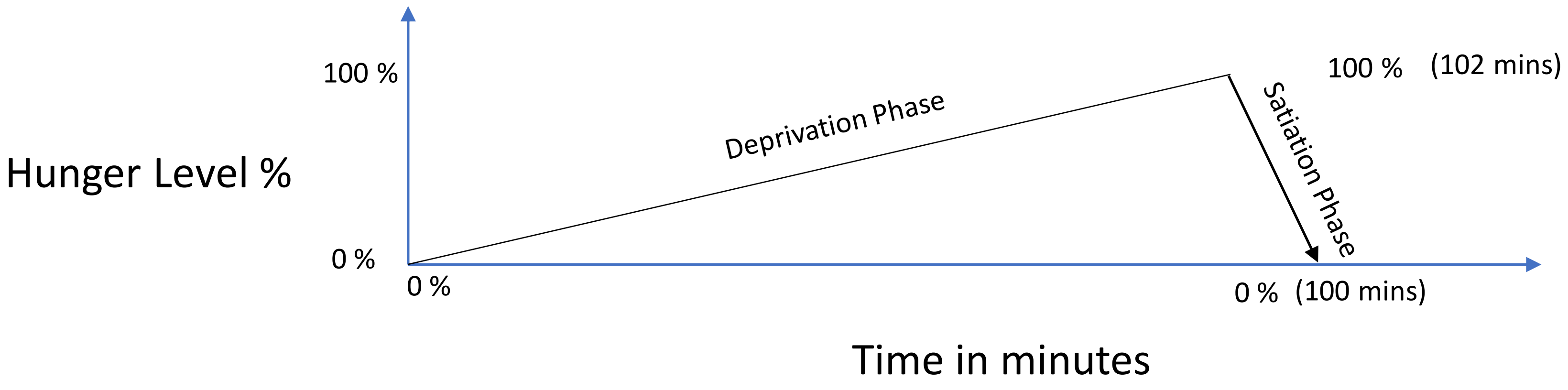
Robot's stomach level (SL) drops at a simulated ‘metabolic rate’ of 1% per minute (slow).

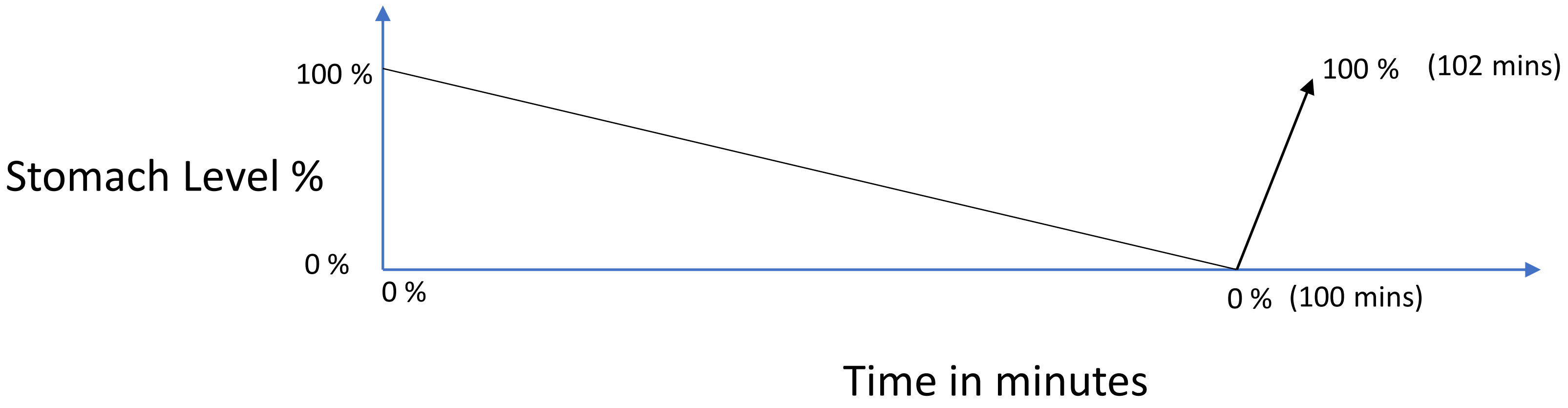
Eating an apple replenishes robot’s stomach level at 50% per minute (fast).

If the robot’s stomach is allowed to be completely depleted to 0% and then filled by eating and apple back to 100%, the time graph will look like this:

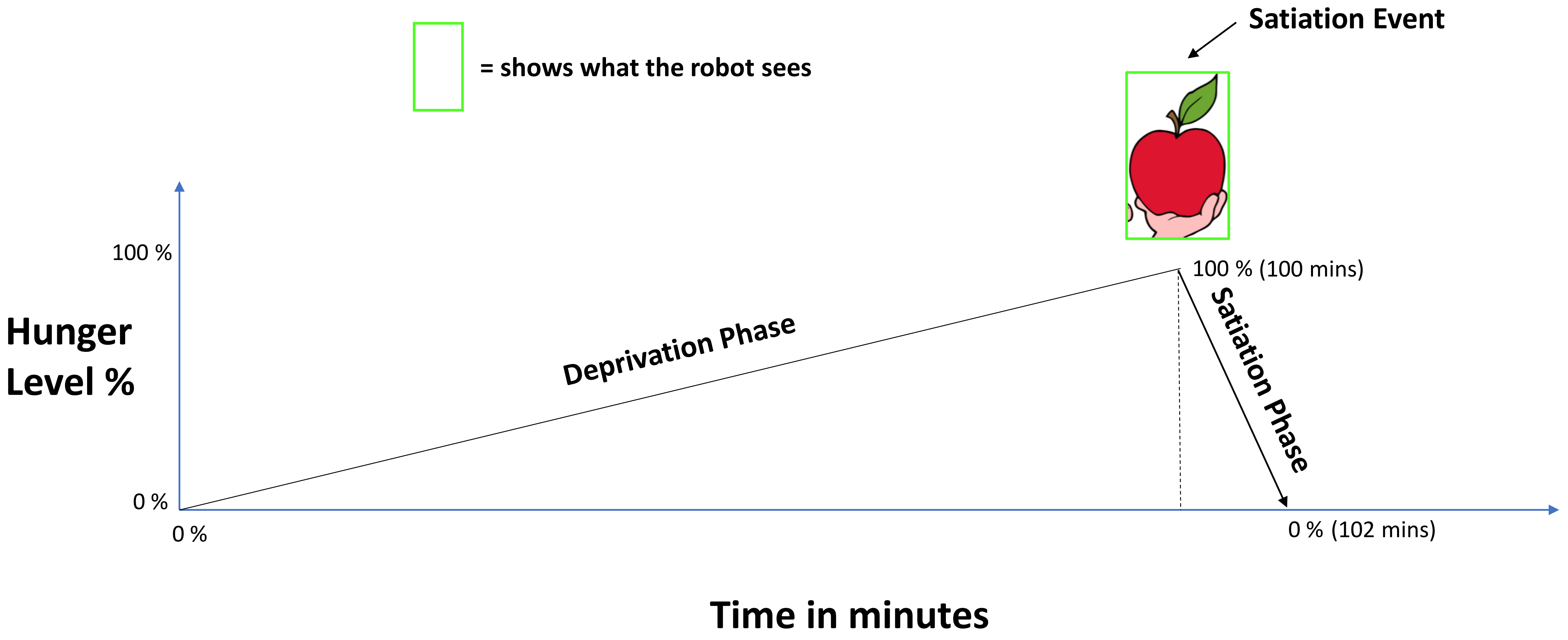


If we plot the Hunger UTR % as a function of Stomach Level (SL) over the same time period:



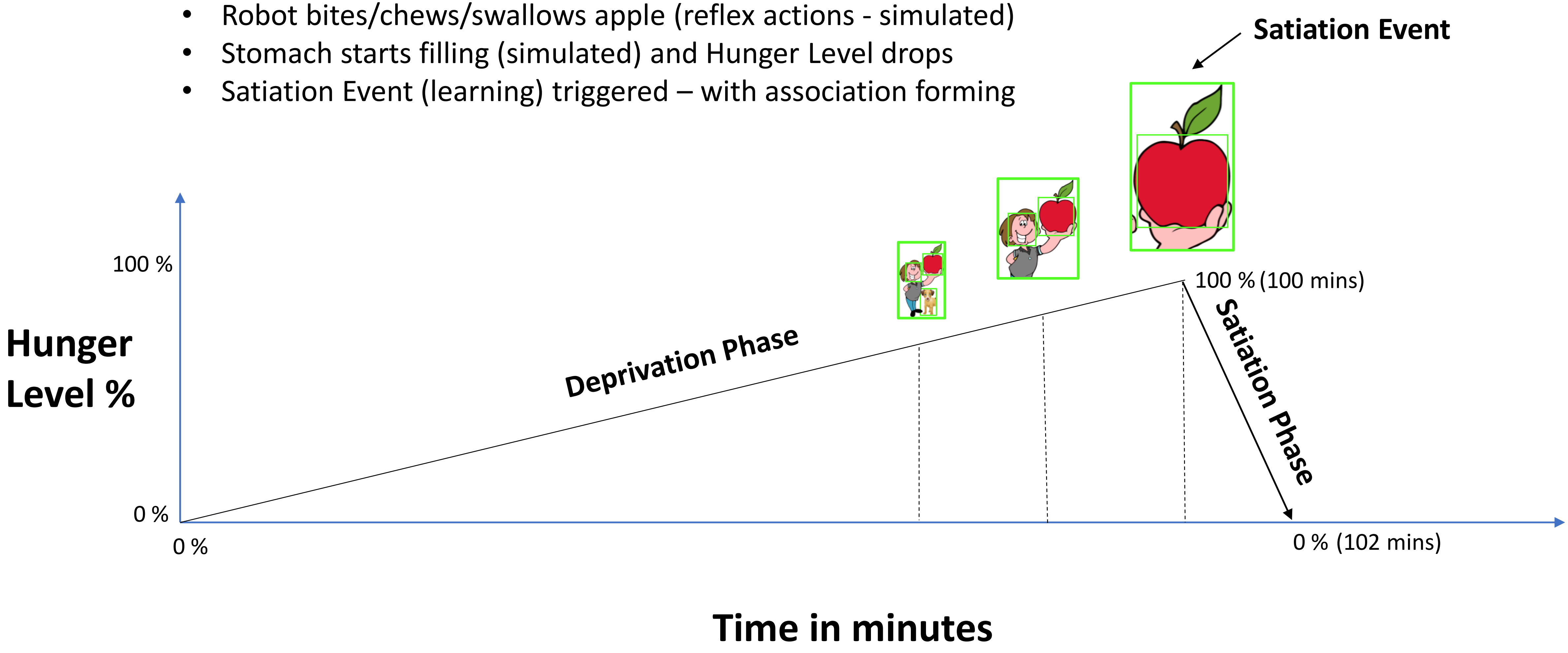


We can assume a Satiation Event i.e. the robot eats a red apple:



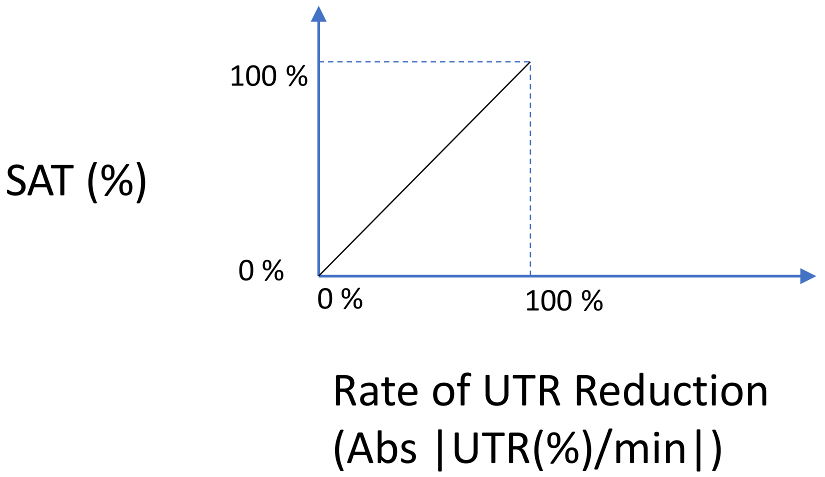
We can assume a Satiation Event i.e. the robot eats a red apple:

- First time encounter with apple and tutor moves robot up to the apple.
- Robot bites/chews/swallows apple (reflex actions - simulated)
- Stomach starts filling (simulated) and Hunger Level drops
- Satiation Event (learning) triggered – with association forming



During the Deprivation phase the **Deprivation Level (%) = - (Urgency To Restore) %**

During the Satiation phase the Satiation Level (%) depends on the rate at which the UTR value is reducing. For simple applications the following relationship gives a approximation to calculate the Satiation level as a %:



If UTR shows no reduction, it means there is no Satiation taking place (SAT = 0%)
If eating the apple reduces the robot's Hunger UTR (%) by 50% per minute, the SAT (%) will be 50%. More sophisticated non-linear models can be used for more advanced robotics applications. **These are called Body UTR emotions.**

There is another mechanism modelled by the Xzistor Concept that also creates ‘avoidance’ and ‘pursual’ states – again based on what happens in the human brain. These states are not part of **Body UTRs**, but originate from **Body UTRs** and as such can also be deemed **Body UTR emotions**.

It is a known fact that when Body UTRs go into Deprivation e.g. humans become thirsty, hungry, etc. the Sympathetic Nervous System (SNS) is activated creating a sensory ‘stress’ state in the gut that is projected through the brainstem to cortical areas including the primary somatosensory cortex. Here it creates a viscerosensory ‘avoidance’ state that will feel like it is coming from inside the body, but in fact comes from the increasing Deprivation of the Body UTR.

When the Satiation Event takes place and the Body UTR’s Deprivation phase goes into the Satiation phase, this activation of the SNS is reduced. This is achieved by the Parasympathetic Nervous System (PNS) which will inhibit the SNS and cause a ‘calming’ feeling which again will feel like it is coming from inside the body, but in fact comes from the Satiation phase of the Body UTR.

For our robot we can model similar Body UTR emotions and call the ‘avoidance’ state the **Body UTR SNS** state and the ‘approach (pursual)’ state the **Body UTR PNS** state.

The **Body UTR SNS** state and the **Body UTR PNS** state (also referred to as pseudo-sensory states) are subjective 'feeling' states that are stored as part of associations, and can be re-evoked when that association is recalled, so that the same **Body UTR SNS** state and **Body UTR PNS** state ('feelings') will be experienced by the robot.

In a simple application the **Body UTR SNS** state / **Body UTR PNS** state values experienced (felt) by the robot and stored during a Satiation Event can be determined as follows.

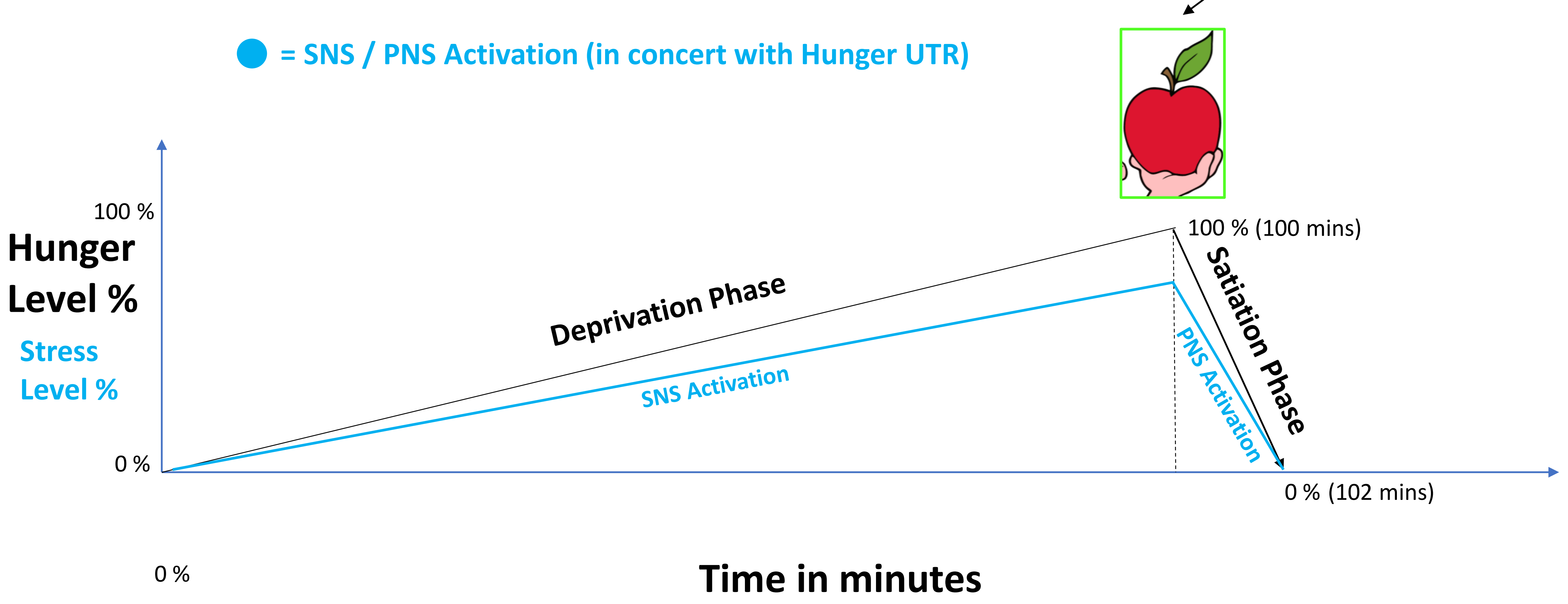
Body UTR SNS % = 0.8 x Body UTR Deprivation %
Body UTR PNS % = 0.8 x Body UTR Satiation %

*Note - the 0.8 value is selected by the designer e.g. the Pain UTR will cause more intense recollections of the **Body UTR SNS** state / **Body UTR PNS** state and the value might move up to e.g. 0.95.*

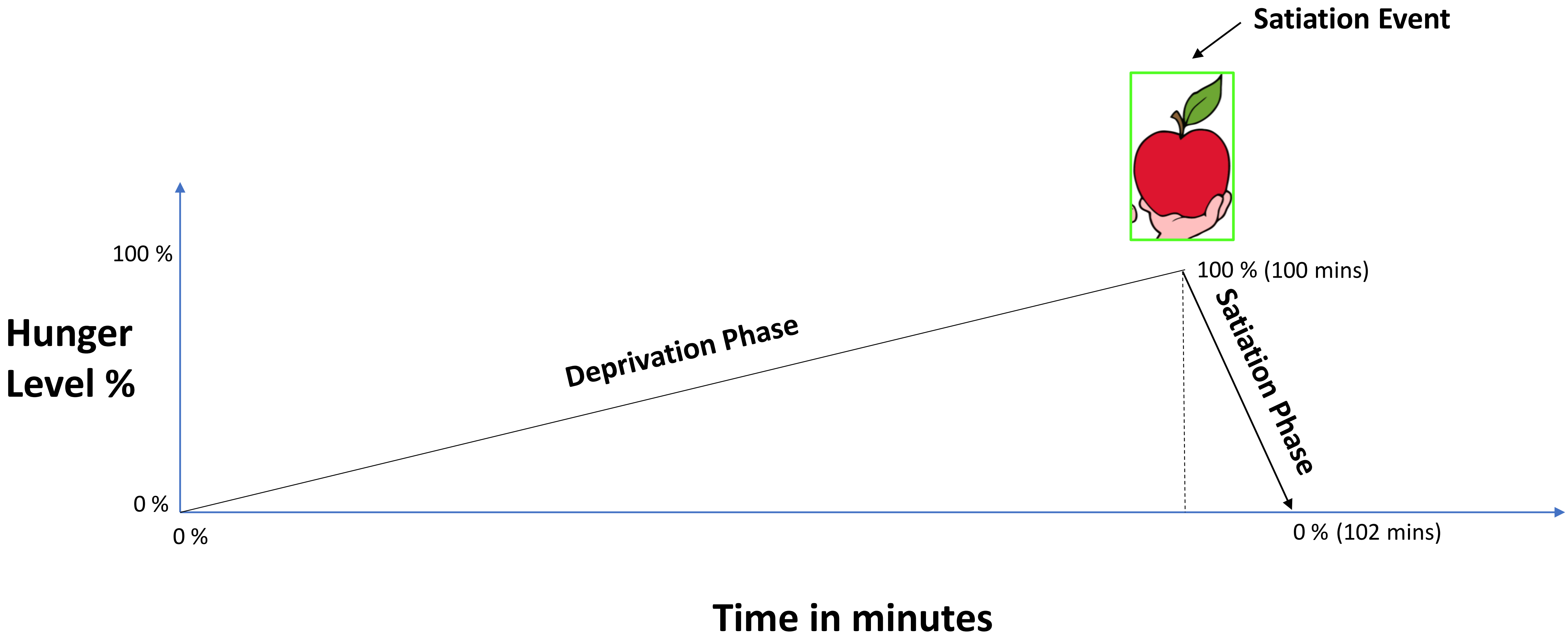
These **Body UTR SNS** state / **Body UTR PNS** state and PNS 'feelings' are also **Body UTR emotions**, but they are weaker in strength to the actual real-time UTR Satiation % and UTR Deprivation % emotions as they are aimed at guiding behaviour / planning in future. If they are recalled at the same intensity level as the original experiences the robot will not eat food but just think about it! ☹

These will also eventually give the robot a 'gut feel' or intuition.

During the Satiation Event, we see the Hunger UTR will trigger the parallel SNS/PNS system and together they will ensure memorisation of 'restorative effector actions' (equivalent to dopamine and adrenaline reinforcement in the biological brain).



If we look at the Satiation Event again, we can now list the available information on that moment that we want to store an association to the robot's memory – a classic case of operant learning (see next slide).



Satiation (learning) Event – to create the association.

The new association will be stored as an entry in the association database e.g. a numbered row with comma separated values for later retrieval by ‘matching’ states. All measured senses will be translated into digital representations (ending up as only 0’s and 1’s).

1) Association ID: 342
2) Optic sense: Red apple (this can just be RGB matrix – or some object recognition enhancements)
3) Tactile Left Hand: Feel apple (just touch – no pressure or pain)
4) Tactile Right Hand: Feel Apple (just touch – no pressure or pain)
5) Hear: “Apple” (tutors voice)
6) Smell: Fruity apple
7) UTR: Hunger (effector actions will only be executed it this indicated Hunger UTR is active)
8) Hunger Deprivation: 0%
9) Hunger Satiation: +50% (will be used for prediction error in future)
10) Pseudo-tactile somatosensory Deprivation state (SNS driven): 0%
11) Pseudo-tactile somatosensory Satiation state (PNS driven): +41% (will not be recalled as intense as original)
12) How often has this association been recalled: 1 (this is the first time it is created)
13) How many time has this association been repeated: 1 (new association being stored)
14) Absolute value of highest of Hunger UTR Satiation Level and Total Deprivation Level
15) Impact Factor = product of 3 bullets above
16) Left wheel motion: Stop
17) Right wheel motion: Stop
18) Left hand: Grip apple
19) Right hand: Grip apple
20) Yaw: Bite, chew and swallow (this mainly will be a reflex)

Before we continue, let's see what we can now do with this association e.g. when next the robot gets hungry and it is in close vicinity of the red apple:

We can 'recognise' the apple (match the optic states) and re-evoke the association.

This will immediately re-evoke the pseudo-tactile somatosensory Deprivation state (SNS driven): 0% in this case, and the pseudo-tactile somatosensory Satiation state (PNS driven): +41%

The stored Hunger UTR Deprivation and Satiation values are not used to re-evoke 'hunger' or 'satiety' as these cannot be regenerated from simple 'recognising' reward sources.

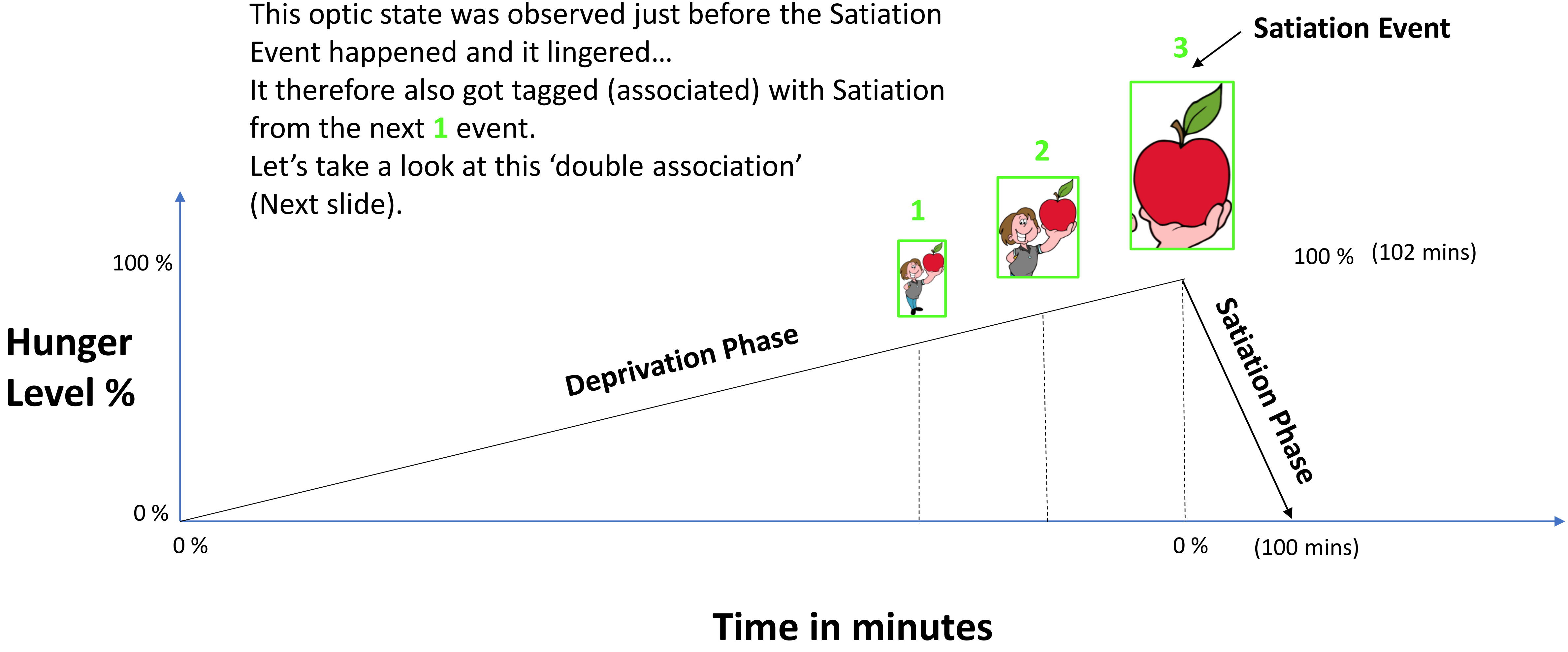
Assume the Hunger UTR is active again when the apple is 'recognised'. The Hunger UTR Dep will be rising, causing the Hunger UTR sensation. The compulsion to execute the learnt behaviours in the association will now be triggered. The moment the apple (reward source) is engaged (bitten into) and the Satiation experienced, this will be compared with the association's Satiation level of 50%. Only if higher Satiation than currently stored in the association is experienced, will a new Satiation Event take place and the Hunger UTR Satiation % and the Hunger PNS Satiation % in the part of the current association will be updated (i.e. based on prediction error). If lower Satiation is experienced the association will also be updated (again prediction error). These updates are influenced by how many times this association had been updated in the past and how recent it is.

If stronger Satiation is suddenly experienced, a Satiation Event will occur and the current motion commands in the association will be overridden and replaced by the current newly reinforced actions for future use.

If the robot is not Hungry (Hunger UTR % lower than 16%) it can still move past the apple and ‘recognise’ it, and this will re-evoke the pseudo-tactile somatosensory Deprivation state (SNS driven): 0% and pseudo-tactile somatosensory Satiation state (PNS driven): +41%. This will create ‘avoid’ dislike / ‘approach’ like emotions only, but not strong compulsions to pursue it. Without the UTR ID present, the association will not trigger the learned grip/eat actions as matching the UTR ID (Hunger is active) will make the difference as to whether the actions are executed or if just the SNS/PNS emotions are regenerated.

Reward-based backpropagation

Look at robot optic sense 2 just before biting the apple.
This optic state was observed just before the Satiation Event happened and it lingered…
It therefore also got tagged (associated) with Satiation from the next 1 event.
Let's take a look at this 'double association'
(Next slide).



Because all the states in the brain at the time of optic state [2] (which preceded the apple eating Satiation Event) still lingered in the brain when optic state [1] was experienced, the association formed for optic state [2] happened at exactly the same time as for optic state [1] and basically 'inherited' the same Satiation levels as the association for optic state [1] as shown below.

1) Association ID: 341
2) Optic sense: Red apple and man's face
3) Tactile Left Hand: None
4) Tactile Right Hand: None
5) Hear: Nothing
6) Smell: Nothing
7) UTR: Hunger
8) Hunger Deprivation: 0%
9) Hunger Satiation: +50%
10) Pseudo-tactile somatosensory Deprivation state (SNS driven): 0%
11) Pseudo-tactile somatosensory Satiation state (PNS driven): +41%
12) How often has this association been recalled: 1 (this is the first time it is created)
13) How many time has this association been repeated: 1 (new association being stored)
14) Absolute value of highest of Hunger UTR Satiation Level and Total Deprivation Level
15) Impact Factor = product of 3 bullets above
16) Left wheel motion: Medium speed forward
17) Right wheel motion: Medium speed forward
18) Left hand: No action
19) Right hand: No action
20) Yaw: No action

This association for optic state [2] preceding the one for optic state [1] can now be ‘recognised’ too.

If the robot is hungry and moving closer to the apple with the help of the tutor, it will now ‘recognise’ the man’s face and the apple from further away, and feel the compulsion to execute the stored motions in the optic state [2] association – in this case simply moving forward with both left and right wheels in the direction of the apple.

Upon recognition the robot will also re-evoke (feel) the predominantly encouraging ‘approach’ emotions of the stored pseudo-tactile somatosensory Deprivation state (SNS driven): -1% and pseudo-tactile somatosensory Satiation state (PNS driven): +49% which it inherited from the optic state [1] association.

Optic state [2] now also has relevance to solving the Hunger UTR and its learned effector motions will simply propel it forward to face the apple – at which point it will ‘recognise’ optic state [1] again (red apple) and follow the learned motions of biting into it, chewing and swallowing.

The robot has now learnt to independently move towards the apple and in exactly the same way optic state [3] will inherit the satiation values from of [2] which originated from optic state [1]. Optic state objects like the man’s face, the dog, etc. from optic state [3] will all trigger this association even when not hungry, and make the robot ‘feel’ positive PNS emotions towards these objects.

Associations can be ‘**anchored**’ to any of the states forming part of the association but for simple applications we normally just require the UTR ID and the optic state, or the UTR ID, optic state and the tactile state to match in order to trigger a ‘recognition’ of the association.

If associations are quickly recalled upon recognition of environmental cues (like optic states) it will lead to a smooth and coordinated motion by the robot. The robot will not even have to Think just execute. But when there are areas *en route* where the robot has not yet learned to navigate, it will have to Think (perform directed Threading) and make guesses (even becoming more desperate and compulsive), or when it gets too hungry just start to cry to attract the attention of the tutor.

The Simmy simulation shows 2 gears turning above the virtual agent’s head when it needs to Think (directed Threading) about finding a way towards the reward source. The Troopy physical (Lego) robot makes a soft beep while the Thinking algorithm is active.

Conclusions (1)

We have seen how a single Hunger UTR (i.e. a Body UTR) can be used to provide a robot with the desire to eat, feel pleasure when eating and related emotions when not hungry that are needed to plan towards finding reward sources and value and contextualise objects it its environment.

We have seen how ‘recognising’ an object will re-evoke an association and mainly lead to SNS/PNS emotions being regenerated. If a UTR is in the Deprivation phase and above its ‘activation threshold’, associations in the robot’s memory related to this UTR will be re-evoked in order to address the urgent need to restore the UTR homeostasis.

Sometimes these emotions re-evoked form ‘recognising’ and object e.g. a snarling dog, will generate a very strong SNS pseudo-sensory ‘avoidance’ state that will also drive behaviour. This we will call a **Brain UTR** as this will also create a state that the robot will learn to Satiate by appropriate avoidance behaviours learnt through operant conditioning.

So in the robot brain, when the Prime UTR is selected to drive behaviours, both **Body UTRs** and **Brain UTRs** will be presented with their ‘urgency’ % values so that they can be compared and the robot brain can decide which is the strongest UTR (Prime UTR) to address first.

Conclusions (2)

To complete the Xzistor Concept brain model only a few functional aspects need to be added.

When Body UTRs are not ‘active’ (above their awareness threshold %) the robot’s behaviour could involve other activities that provide Satiation like playing, watching TV or just daydreaming. During daydreaming these same associations will be recalled as in ‘mind wandering’ (Threading) mode. It is here that the part of the association related to ‘Absolute value of highest of Hunger UTR Satiation Level and Total Deprivation Level (saliency)’ is used to decide which associations are recalled based on strongest saliency (good or bad), recency and recentness. These structured meanderings through the association database creates ‘context’ around an observations or ‘thought related associations’. It further plays a role in Thinking (directed Threading) where again saliency help to prioritise relevant and historically impactful learnt knowledge.

When the robot sleeps it also performs mind wandering (Threading) based on these saliency values attached to associations via the Impact Factor attribute but effector execution is inhibited.

All these aspects collectively allow for a ‘principal’ understanding of the brain and a way to mathematically model its processes and demonstrate it under dynamic conditions in simple simulations or robots.

Conclusions (3)

As urgency (Hunger UTR Deprivation) increases the compulsion to perform the learned actions of the association will increase and efforts will become focused through directed Threading allowing fewer and fewer unrelated thoughts (even those with strong salience) to influence behaviours. The robot's actions will become desperate and it will have a big frown and start to cry if it does not know how to move to the reward source.

If a robot follows a navigation route i.e. move from one cue (e.g. observed object in the environment) to the next based on the way they have been associated with the route to the reward source by reward-based backpropagation, no Satiation Event can take place unless an increase in Satiation above what has been expected is encountered or a similar learning event due to a lower Satiation value (disappointment). In the latter instance the association gets updated with higher Deprivation % and lower Satiation % values to indicate it is less important to finding the reward in future.

For a typical Pain UTR the subjective pain Deprivation state will shoot up quickly and the Satiation state will be subjectively experienced more as a release or relief from pain than a 'pleasure' – but the mechanism is the same, reward and aversive events are handled by the same algorithm.

Video

Watch the video on the next slide to see how this type of learning can lead to a robot independently navigating to a reward source when it gets hungry without further training. When Troopy senses that he is ‘touching’ the green mat on the confine floor it effective tells him he has reached the food source (equivalent to seeing and touching the apple). This video includes a further demonstration to show that an interim action will also be learned to push a button first before the food source can be accessed. This all happens die to operant conditioning.

Video of Troopy undergoing some training in its learning confine

https://www.youtube.com/watch?v=QyAv9ujV9Yw