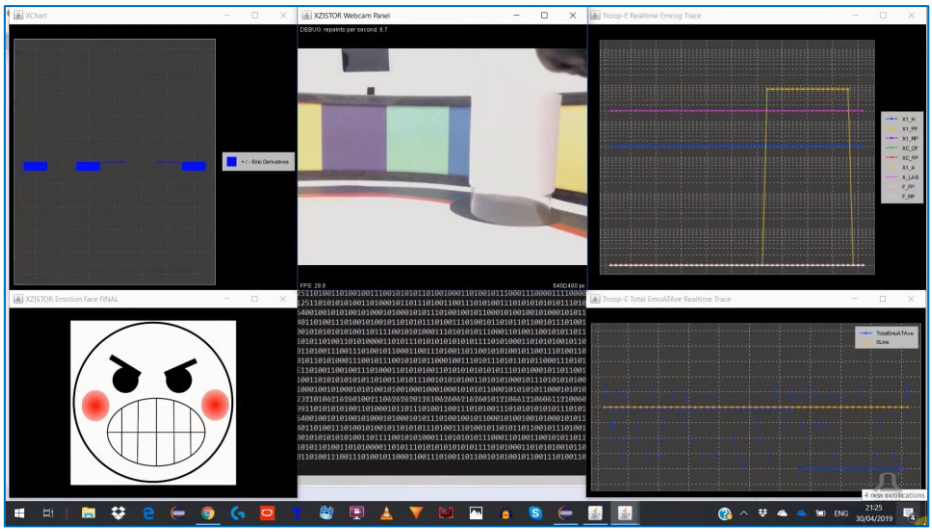

How are Emotions created by the Xzistor Concept?

Rocco Van Schalkwyk 1/10/2022

The Xzistor Concept brain model provides a complete ‘simplified’ explanation of how emotions are created in the brain. This is based on an integrated set of functions which the model proposes are present in the biological brain. The manner in which the Xzistor

Concept defines emotions allows for mathematical modelling which in turn can be built/coded into artificial agents like robots. A simulation and a physical robot was used to demonstrate the working of this model under dynamic conditions e.g. when the agent moved around a 'learning confine' and interacted with its environment including the generation of emotional states while daydreaming and sleep dreaming.

Let's first look at behaviours. The Xzistor Concept specifies a few ways in which a physical behaviour can be caused:

- Reflexes
- Phobias and instinctive fears
- UTRs [Body UTRs (real-time) and Brain UTRs (from memory recollection)]

These 5 functional mechanisms (and only these) can lead to a physical behaviour by an Xzistor robot.

- *Reflexes* – an example of a behaviour triggered by a Reflex would be instinctive retreating out of a thorn-riddled patch after stepping onto some thorns, or instinctively pulling away a hand from a hot stove plate. No learning required.
- *Phobias and instinctive fears* – an example of a behaviour triggered by a Phobias or instinctive fear would be instinctively retreating from a dark cave, or instinctively reversing out of a tight tunnel due to claustrophobia. No learning required.
- *UTRs* – an example of a behaviour triggered by a Body UTRs would be eating an apple when hungry – this is a learnt behaviour (operant learning). An example of a behaviour triggered by a Brain UTR would be reversing away from an active wasp nest where pain had been experienced in the past out of fear of experiencing that pain again - this is also a learnt behaviour (operant learning).

For the explanation of how emotions originate, we will first look at UTRs.

1.1 The Body UTR

The typical Body UTR is a functional control mechanism that includes urgency-based homeostatic control of a utility parameter/state in combination with operant learning.

If the utility parameter moves out of balance, the Body UTR will calculate the increasing 'urgency' for the utility parameter to be restored to ensure 'health' and 'well-being'. The further the utility parameter moves away from its homeostasis state over time – the more urgent it will become for the system to take action to restore the utility parameter to its homeostasis state (this is called the Deprivation phase of the UTR curve). But unlike most negative-feedback control systems, this response is not specified up front and needs to be learned through operant conditioning. This can take place through a tutor e.g. guiding the agent to an apple when it is hungry and assisting it to reach out, hold and eat the apple. The moment the apple is ingested, the 'urgency' calculated by the Body UTR starts to drop (i.e. error signal is reducing). The apex of the curve where the Body UTR curve inflects, we will refer to as the Satiation Event. The phase that follows where the urgency value calculated by the UTR is dropping, is called the Satiation phase. The reward-securing agent actions (e.g. grab, hold, eat apple) are stored to memory via operant conditioning in a way that turns these actions into future instructions (compulsions) to be executed next time the agent is hungry and facing an apple in that environment. The apple grabbing, holding, eating behaviour now becomes the learnt response to an out-of-balance hunger UTR state (error signal) in that environment if an apple is visually detected.

To allow mathematical 'comparison' between simultaneous Body UTRs, the urgency to restore can be assigned a percentage value % depending on how important for survival/procreation it is to restore the utility parameter to its homeostasis state. A simple approach would be 0% urgent when perfectly in balance moving up to 100% urgent when severely (critically / fatally) out of balance.

By combining 'homeostasis principles' and 'urgency' with 'operant learning', we can make the Xzistor agent 'learn' the correct effector actions in response to an out of balance utility parameter belonging to a specific Body UTR. This means the Xzistor agent

will remember what it did when hungry and facing the apple – i.e. it will reach out, grab the apple and eat it.

The problem with this approach is that the Xzistor agent will only ever learn to manually grab, hold and eat the apple when hungry and presented with it. Then, as the apple is recognised (matched with visual image in memory) the associations will be recalled and trigger the learned effector motions that had been stored as compulsions along with the sensory cues of the environment and the apple as the reward-source object. What is missing here is the fact that the Xzistor agent will not learn to move around the environment and navigate complicated terrains to get to the food. To achieve this another functional component must be added to the Body UTR control mechanism.

This is the functional construct of emotions.

Before we start our discussion on emotions, we must remind ourselves that there is only information in the brain. If we want the brain to do something, we must tell it through Reflexes or other instinctive behaviours (e.g. Phobias), or it must act on cues from within the body or the environment. Things in the environment we want the brain to approach (pursue) we can translate through the senses into a brain state or representation (just information) and then reward the brain if the pursual was successful – telling it to remember the effector actions that led to finding the desired state. This is exactly what a Body UTR does. This will be a good thing (object) in the world of the brain as this could be related to survival. Similarly, things in the environment we want the brain to find aversive (avoid), we can translate through the senses into a brain state or representation (just information) and then reward the brain if the avoidance was successful – telling it to remember the effector actions that led to avoiding the aversive state. This will be a bad thing (object) in the world of the brain as this could be related to injury/death. Again, this can be achieved with a Body UTR. And because each UTR has an urgency % associated with it, the brain can compare these to decide which it should first pay attention to and resolve as a priority.

Where the brain is taught to avoid certain states (internal representations), we can refer to these as 'avoidance' states, and when the brain is taught to approach (pursue) certain states, we can refer to these as 'pursual' states.

The only thing that can ever be good in the brain – is a 'pursual' state, or the annihilation of an 'avoidance' state. The only thing that can ever be bad in the brain – is an 'avoidance' state, or the inability to achieve a 'pursual' state. These are just representations – and all 'feelings' - as intense and complex as they might seem - are just a composition of current 'avoidance' and 'pursual' states.

So as we start our discussion on emotions, it is important to remember that emotions are just information in the brain – and the associated 'feelings' are also just states (representations like neuronal activation patterns) that have become either 'avoidance' or 'pursual' states. Experiencing life leads us to experience many of these complex states and we find names to describe them like – pleasure, happiness, sadness, hunger, gratification, delicious, weary, ecstatic, etc. But we must always remember that they can only ever exist as 'information' although we sometimes want to believe these emotions are so intense that it entails something more than just information, or in the case of a digital instantiation, more than just zeros and 1's.

When we now return to the Satiation Event – that moment when the Deprivation phase suddenly transitions into the Satiation phase – we know we want this to be a learning event. This will make the representation of hunger in the brain an avoidance state (bad) and the representation of eating in the brain a pursual state (good). *Note: We are not saying that avoidance and pursual states can only be learned and cannot pre-exist innately in the brain*. So we know that substances like dopamine in the biological brain will act during Satiation to store the actions that led to eating the apple (and preceded it to some extent). The human might explain this experience and 'pleasurable', 'nice' etc. which are just words that had become associated with the eating pursual state. The dopamine has now performed its main task of storing the association and rewarding the effector motions that lead to the ingestion of the apple. In the model the dopamine release will be represented by the Satiation experienced and this Satiation level will in

itself become part of the association – being re-evoked as exactly the same Satiation level when next time hungry and the apple is recognised. Because dopamine acts on a 'change' or 'difference' in Satiation value, the stored Satiation level will only be changed / updated if the apple next time tastes better or worse. Else the re-evoked Satiation level upon recognising the apple will match the actual Satiation level during eating and because there will be no change, the Satiation level modelled on dopamine action will not increase or decrease – and this will not lead to updating the associations stored. If the apple suddenly tasted better and trigger higher Satiation, this will trigger the system to update the association with the actions that where performed to eat the apple and also update the Satiation level in the association.

In the Xzistor model it is therefore crucial that some of the attributes included in an association are:

- Optic sense: Apple (**viewed close up**)
- Tactile: Round, smooth, medium weight
- Scent: Floral
- Effector Action Mouth: Chew
- Effector Action Left Hand: Hold apple
- Effector Action Right Hand: Hold apple
- UTR: Hunger
- Body UTR Hunger Satiation Level: 87%
- Body UTR Hunger Deprivation Level: 0%
- Brain UTR Satiation Level: 87%
- Brain UTR Deprivation Level: 0%
- Number of times association recalled
- Time expired since association last recalled
- Absolute value of highest of Total Satiation Level and Total Deprivation Level
- Impact Factor = product of 3 bullets above

We will look in a minute at what is meant by Brain UTRs. But first we must consider a very important effect of storing associations which include the information above. As we have mentioned, during the Satiation Event, not only the actions of eating the apple is stored but also those preceding it (those motions that still lingered in the brain when biting into the apple for the first time). The preceding association could look like this:

- Optic sense: Apple (**viewed while approaching kitchen table**)
- Tactile: None
- Scent: None
- Effector Action Mouth: None
- Effector Action Left Hand: Starting to reach towards the apple
- Effector Action Right Hand: Starting to reach towards the apple
- UTR: Hunger
- Body UTR Hunger Satiation Level: 87%
- Body UTR Hunger Deprivation Level: 0%
- Brain UTR Satiation Level: 87%
- Brain UTR Deprivation Level: 0%
- Number of times association recalled
- Time expired since association last recalled
- Absolute value of highest of Total Satiation Level and Total Deprivation Level
- Impact Factor = product of 3 bullets above

The above association is credited with the same Satiation level as eating the apple itself – even while just moving towards the apple. This means next time the Xzistor agent is hungry and reaches this location (and view the apple from a distance) it will feel the same level of Satiation as when eating the apple. This is similar to how dopamine works. This means reaching this location will effectively act as a Satiation Event and act as a hunger reward state - and cause Satiation (trigger dopamine) as there will be a sudden change in Satiation value from zero to 87% even though the apple has not yet been

reached. Again the preceding sensory states and effectors actions (e.g. moving towards kitchen door) will become rewarded with the same Satiation. In this manner progressively further away locations (with their sensory cues) will become 'reward states' and with the help of these *en route* Satiation Events the actions will become enforced as motions to be repeated when next hunger is experienced. This is called reward-based backpropagation by the Xzistor model, and it is how the Xzistor agent will learn to navigate to the food source (apple) from far away. This was demonstrated in Xzistor simulations and physical robots.

An apple, as an object in the environment of the Xzistor agent, can have associations (like listed above) for different Body UTRs e.g. hunger, thirst, pain, fatigue, etc. This means that although the apple might not be a reward source for those Body UTRs, it might act as a navigation beacon *en route* to solving the UTR and still become associated with a level of Deprivation or Satiation.

1.2 The Brain UTR

What is meant by Brain UTRs can now very easily be explained by what had been presented above. It should be clear that dopamine performs an important function in storing appropriate associations to link effector actions with UTRs in Deprivation during actual and *en route* Satiation Events. Because this leads to the Xzistor agent moving from an 'avoidance' state to a 'pursual' state it will create a reward state that we will refer to in subjective human terms as 'satisfying' or 'pleasurable'. It can of course only ever remain information exchange states, as mentioned before.

But there is another mechanism at work in the brain that also creates 'avoidance' and 'pursual' states – namely the autonomic nervous system (ANS) comprising the Sympathetic Nervous System (SNS) and Parasympathetic Nervous Systems (PNS). Simply put, the SNS causes stress e.g. the Fight or Flight (FoF) Response and the PNS counters that with a state of relaxation or calm. Except for the Reflex reactions that trigger the FoF i.e. the SNS, we find that activation of the thirst centre, hunger centre and pain centre, etc. in the brain also triggers the SNS causing a stress state which is transferred to the

gut (vagus nerve) and then projected to the brain via the brainstem as a visceral somatosensory body state (sometimes referred to as a pseudo-tactile or pseudo-somatosensory state). The SNS representation in S1 is also an 'avoidance' state and our actions are rewarded when we move out of this state and into the calming PNS state. Because the SNS and PNS become activated in concert with the UTRs (SNS activation during the Deprivation phase and PNS activation during the Satiation phase), it becomes another type of Deprivation and Satiation that the Xzistor agent will experience with learning events (Satiation Events) that can be added to associations. And importantly, these avoidance and pursual states can actually be re-evoked (regenerated) from memory e.g. when we look at a reward object like an apple, or a glass of fruit juice – we feel slight PNS activation as if a relaxation / calming in the gut. UTRs' inherent avoidance and pursual states cannot be re-evoked by just looking at objects – we do not feel thirsty when we think about it and we do not feel the pleasure of quenching if we just think about a glass of fruit juice. But this is different for the SNS and PNS states created in the colonculus of S1, as even just thinking about objects can re-evoke the SNS or PNS states that was stored during association events. We can now literally feel a sense of Deprivation (SNS) in our guts if we just look at the dog that bit us, or we can feel a sense of Satiation (PNS) when we look at photographs of sandy white beaches reminding us of our island holiday. So when we are in Body UTR Deprivation, we will predominantly be aware of the Body UTR avoidance state (generated in its dedicated brain centre), and when we are in Body UTR Satiation, we will predominantly be aware of the Body UTR pursual state (it could be in the same dedicated brain centre or elsewhere).

This is important because often the Brain UTR will generate a Brain UTR Deprivation state just from seeing and recognising a dog that bit us some time ago, and this will compete with some Body UTRs telling us we are thirsty and hungry. We will now prioritise the dangerous dog and perform the learned behaviours to move into the yard and close the gate behind us, before contemplating finding food or something to drink. Just like Body UTRs, the Brain UTRs could lead to long trails of reward-based backpropagation that could for instance cue back from a very painful event (stabbing) causing us to avoid travelling to a certain part of town, telling others not to travel to that area and even

deciding not to talk about the stabbing event because of the Deprivation (re-evoking SNS activity) in causes. People sometimes change jobs because of stress (SNS) in the workplace. Our behaviours become the result of the competition between Body UTRs and Brain UTRs and the Prime UTR will be the one that is the strongest and which is performed – this could be a Body UTR (thirst, hunger, too cold, too hot, pain, fatigue, sex, itch, etc.) or a Brain UTR (fear of pain, fear of a dangerous animal, anxiety while trying to get out of a traffic jam, etc.)

The Xzistor model makes building emotions into robots easy by using these theoretical constructs and by giving both Body and Brain UTRs a current value of 0 to -100 Deprivation or a current value of 0 to +100 Satiation. The total emotion state an Xzistor agent will experience at any given point in time will be all the non-zero Body UTRs and Brain UTRs combined as shown below. If an Xzistor agent is given 5 Body UTRs, the total emotional state at any given moment in time can be determined as follows:

Body UTRs (5)

Body UTR1 emotion in UTR1 brain centre: = Satiation + Deprivation (e.g. 87 + (-13) = 74 Satiation

Body UTR1 emotion in S1: = PNS + SNS (e.g. 44 + (-3) = 44 Satiation

Body UTR2 net emotion = Satiation + Deprivation (e.g. 56 + (-0) = 56 Satiation

Body UTR2 emotion in S1: = PNS + SNS (e.g. 38 + (-0) = 38 Satiation

Body UTR3 net emotion = Satiation + Deprivation (e.g. 0 + (-17) = -17 Deprivation

Body UTR3 emotion in S1: = PNS + SNS (e.g. 0 + (-7) = - 7 Deprivation

Body UTR4 net emotion = Satiation + Deprivation (e.g. 0 + (-22) = -22 Deprivation

Body UTR4 emotion in S1: = PNS + SNS (e.g. 0 + (-13) = - 13 Deprivation

Body UTR5 net emotion = Satiation + Deprivation (e.g. 2 + (-34) = -32 Deprivation

Body UTR5 emotion in S1: = PNS + SNS (e.g. 1 + (-28) = - 27 Deprivation

Brain UTR (there can only be 1)

Brain UTR1 net emotion = Satiation + Deprivation (e.g. 0 + (-89) = -89 Deprivation

Based on the 5 Body UTRs above the Xzistor agent might be modelled to be eating a hamburger and drinking a fruit juice - so have two Satiation sensations whilst feeling a little Deprivation due to cold weather and perhaps a little fatigued from going for a run. And the 1 Brain UTR could be driven by a strong SNS state evoked from memory because it is viewing a very steep mountain path that makes for a very strenuous walk. The Xzistor agent will firstly act to avoid the walk up the mountain so the Brain UTR will be the Prime UTR (it is a case of fear of exertion is stronger than all other competing Deprivation states). The emotions associated with Body UTRs are subjectively sensed in dedicated Body UTR brain centres as well as the SNS and PNS system projecting to the intra-abdominal and intra-trunk ('gut areas') of the primary somatosensory cortex S1 (or similar). All the Body UTRs will be experienced subjectively via representations in dedicated areas of the brain while all the contributions from the Body UTRs to S1 (SNS or PNS) will be synthesized with the S1 (SNS or PNS) state coming from the Brain UTR. The consolidated (net) S1 state is obtained from adding the highest PNS % value to the highest SNS -% value. This will end up with either a net positive PNS % value or a net negative SNS -% value for the Brain UTR.

We will therefore have 5 x distinct net Body UTR sensations and 1 x net Brain UTR sensation that will constitute the total synthesised emotion state on that given moment in time.

To determine the size of frown or smile on an Xzistor robot's face we can simply take the largest of either the a.) Body UTR emotions (Deprivation or Satiation) or the b.) Brain UTR (Deprivation or Satiation) and use the largest Deprivation of a.) and b.) if both a.) and b.) are in Deprivation or largest Satiation of a.) and b.) if both a.) and b.) are in Satiation. If one of them a.) or b.) is in Satiation and the other is in Deprivation, then simply add the two values (+ and -) together. If the result is – it means the net emotion is Deprivation (frown) and if the result is + it means the net emotion is Satiation (smile).

It is important to also discuss the parasitic nature of UTRs and the emotions they create. If we take the example of a marathon runner that is running up a mountain on a blazing hot day. The body now needs to tell the runner not to overexert himself. The Fatigue

UTR can now start to generate an 'avoidance' state which could innately or via operant learning start to try and compel the runner to slow down. But the runner wants to win the marathon for the prize money and overrides the Body UTR compulsions which tries to stop him. Other Body UTRs now start to kick in as the runner becomes unpleasantly hot and starts to sweat profusely. The Too Hot UTR is now also instructing the runner to stop. Sweating now starts to lead to loss of water and osmolality shoots up. The Thirst UTR kicks in trying to force the runner to stop and drink water. Next the Pain UTR kicks in and generate muscle pains in the legs. The emotional state of the runner is now not just revolving around fatigue anymore – it has become complex. He is getting so out of breath that his lungs start to burn (a new Lung Pain UTR) and he can't get enough oxygen into his blood causing the Oxygen UTR to kick in – trying the make the runner stop and breath properly to remove CO2 from his blood.

The scenario above shows how UTRs can act together to multiply the Deprivation effect an also explains why eventually stopping to rest and drinking ice cold water can bring such huge relief. The cumulative Deprivation was extremely high, and the Satiation curve very steep as all the UTRs are relieved at the same time – making for intense relief and pleasure when quenching with ice cold water.

Although an emotion can be blamed on a single Body UTR e.g. aggression, in truth it very quickly becomes a composition of FoF, Too Hot, Thirst (dry mouth) and other UTRs working in unison. So it should be kept in mind that it is almost impossible to avoid this interaction where Body UTRs work in unison, and their effects are augmented by the fast-changing Brain UTRs that originate from associations which could evoke many different fears in the mind (collectively referred to as Base Fear by the model) caused by Threading and directed Threading that constantly changes the context of what is being thought about.

1.3 Conclusion

We see that the total emotion state at any given point in time for an Xzistor agent will be the composition of Body UTR and Brain UTR triggered avoidance (Deprivation) and pursual (Satiation) states. The Body UTRs will create emotion states in their dedicated areas (centres) as well as in S1 (SNS or PNS). The Brain UTRs (recalled from memory) will create emotion states in S1 (SNS or PNS). All the emotions states in S1 will be consolidated into a single SNS or PNS state, which will be experienced along with all the Body UTR states (either Deprivation or Satiation) in their dedicated brain areas (centres).

The combinations of emotions that can be experienced by even a simple Xzistor agent with 5 x Body UTRs and 1 x Brain UTR (working with % scales) over a period of a few days or weeks, could run into millions. Brain UTRs can in addition very rapidly change their SNS or PNS states originating from recalled associations during Threading or directed Threading. So during the period while fruit juice was consumed, many different thoughts could have been recalled, evoking different positive and negative emotions weakening or strengthening the net emotional state related to the enjoyment of the fruit juice. We might also rather go to another juice bar and order the same drink just because the current bar reminds us of a bad time in our lives. The quench experience might be the same, but total Satiation is affected by Deprivation purely caused by our thoughts. This lower Satiation value will back-propagate all the way to when we left our house in our car – compelling us to drive to the venue without the bad memories.