

The Structural Engine Model of Consciousness

PRIMAL EXAMPLE: Waiting at the Traffic Light

While driving her car, Jan is waiting at a red traffic light. Then the light turns green. Jan releases the brake pedal and clutch pedal, presses on the accelerator pedal and starts the car forward.

To investigate this activity, I suggest that a “Structural Engine” operating in Jan’s brains responds to the change in the traffic light and works the pedals. In the car, a gasoline engine turns the drive shaft and the tires engage the road, thus propelling the car forward. I suggest that the “Structural Engine” described here operates in a similar fashion and that Jan uses something like structural engines to operate her body and run her life.

The chief parallel is the action of a “clutch.” I use the name “Clutch” to model activity in Jan’s brains that is “just like” a corresponding activity involved in getting a car going. The central event is *release* of a Clutch that opens a *transmission channel* needed for expression of activity. An important circumstance is that Jan is *ready* to get going.

Readiness, release/trigger and *discharge* through a transmission channel (followed by *relaxation/recharging*) is a course of events that re-appears at every level of physiology and psychology, from the activity of a single neuron to that of an entire organism, and from simple sensory-motor bodily experiences like Jan’s to principled political action of an organized community. I suggest that this course of events is suitable for imitation through general principles.

At the center of the Model is a Structural Engine. Like all engines, a Structural Engine operates in a cyclical fashion and works with two kinds of phenomena. A Heat Engine (e.g., a steam engine) works with heat and mechanical work. This Structural Engine works with objects and acts. The result is a particular variation of that familiar general structure: {red–stop, green–go}. That is, the stroke of the Structural Engine produces an instance of that structure from the particular objects red light and green light and from the particular acts of waiting and driving. The particular instance is {redlight–waiting, greenlight–driving}. The Structural Engine shifts from redlight–waiting to greenlight–driving.

To set forth the steps in the action of the Structural Engine in more detail:





(1) Jan is waiting at the traffic light, which she sees is red. The car is in first gear so there’s no need to operate the gearshift. Jan’s left foot is pressing on the clutch pedal and Jan’s right foot is pressing on the brake pedal.

(2) Then, the light turns green.

(3) Jan shifts her right foot from the brake pedal to the accelerator and presses on the accelerator, coordinating the acceleration with the release of the clutch pedal.

These steps form a pattern that Jan and millions of other persons follow every day. Following J. A. S. Kelso, *Dynamic Patterns: The Self-Organization of Brain and Behavior* (1995), I use the term “**dynamic pattern**” to identify activity that has two interdependent aspects or parts: (1) electro-chemical activity in the physical matter of brains and (2) mental or cognitive processes.

In the example of “Jan waiting at the traffic light,” there are four dynamic patterns that occur, at various time, in Jan’s brains and mind. I identify the dynamic patterns with matters in Jan’s experience and Jan has the following experiences during the example:

1. Sees that the traffic light is red: the “red dynamic pattern.” 
2. Sees that the traffic light is green: the “green dynamic pattern.” 
3. Waits at the traffic light – pressing on clutch with left foot and pressing on brake with right foot: the “yellow dynamic pattern.” 
4. Drives the car by shifting the right foot and releasing of the clutch pedal: the “blue dynamic pattern.” 

Brain science provides a framework for thinking about such dynamic patterns. In brief, I suppose that biological cells in brains, neurons, are organized into assemblies of groups that generate and maintain physical activity chiefly in the form of electrical impulses and chemical discharges. In the Thermal Model, a unit is called a “Neuronal Group.” There are many interconnected Neuronal Groups; and the Model supposes that a chief business of brains is the origination and modulation of electro-chemical activity of Neuronal Groups internally and through their interconnections. Each Neuronal Group is a node in a network and nodes are interconnected through bundles of neurons that act like cables from one Neuronal Group to another Neuronal Group.

In the Model, I suppose that there are systems where a signal in the form of a pulse travels coherently through a series of Neuronal Groups and returns repeatedly to each Neuronal Group in the series in a cyclical, repetitive pattern. Such a **cyclical, repetitive** pattern constitutes an **object** in the Thermal Model that is a **phase**. A phase in the Thermal Model is more specific than and different from a dynamic pattern as that term is used by Kelso. In The Thermal Model, the cyclical, repetitive nature of such dynamic patterns makes them especially suitable for investigation. E.g., each such pattern involves a **conserved quantity**. A structure of Neuronal Groups involved in maintaining a cyclical, repetitive pattern is called a Neuronal Group Assembly.

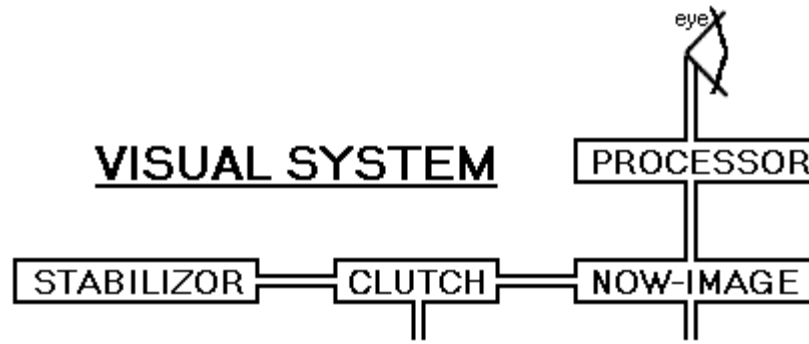
From another direction, a Neuronal Group Assembly is supposed to be like an anatomical region in a brain that specializes in certain kinds of experience, e.g., activating muscles in the arm or sensing muscle activations, positions and/or motions of parts of the arm. I suppose that each Neuronal Group Assembly can support several different phases, but there are phases that exclude each other. For example, in the example of Waiting at the Traffic Light, “red” and “green” exclude one another and “waiting” and “driving” exclude one another. On the other hand, a person can “wait on green” or “drive on red,” although these particular structural combinations might be foolish or illegal.

A “System” includes several Neuronal Group Assemblies. In the example of Jan Waiting at the Traffic Light, one set of Neuronal Group Assemblies, the “Visual System” can generate and maintain either the redlight dynamic pattern (“the light’s red”) or the greenlight dynamic pattern (“the light’s green”). Another set of Neuronal Group Assemblies, the “Motor System” can generate and maintain the yellow dynamic pattern (“waiting”) or the blue dynamic pattern (“driving”).

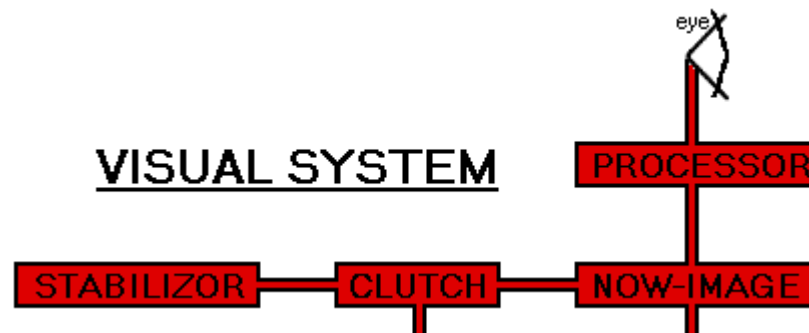
The Structural Engine Model uses a structural diagram to set forth the functional organization of Neuronal Group Assemblies in Jan’s brains. A box indicates a Neuronal Group Assembly and a connection indicates a channel for energy transfer between assemblies.

In the structural diagram of Jan’s brains in the image below, I model activity of seeing the traffic light and observing the change through a “Visual System,” with the following parts and connections:

1. The Processor that receives visual signals from the eye and produces a Now-Image, shown as if maintained in a separate part of the model for the sake of clarity.
2. The Now-Image that, in this example, need show nothing more than “redlight” or “greenlight.”
3. The Stabilizer that “fixes upon,” confirms and maintains the Now-Image as long as stabilization is possible. A Stabilizer is a mirror with a brief memory; that is, there is maintenance of a dynamic pattern with sufficient endurance to be self-sustaining in the presence of continually-maintained confirmation by means of Now-Image but not otherwise.
4. The Clutch, or the “Visual Clutch” when appropriate.

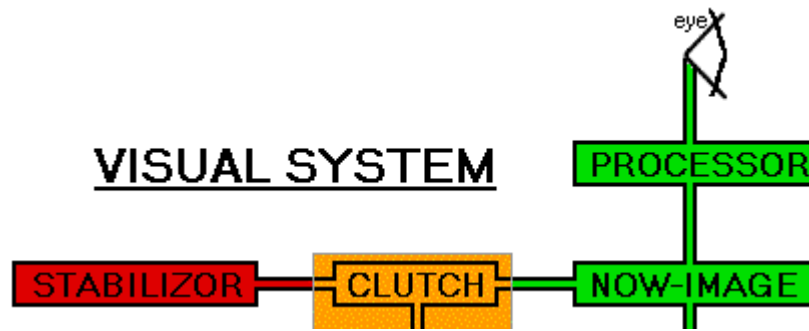


In the Model, the way a Clutch has two states. In the first state, an *engaged state*, as in the Visual System in the image below, the Clutch is serving as a connector between the Now-Image Neuronal Group Assembly and the Stabilizor Neuronal Group Assembly. In other words, Now_Image and Stabilizor engage each other through the Clutch. In this state, the function of the Visual Clutch is like an that of an automobile clutch set that “engages the drive shaft.” The channel maintained through Visual Clutch sustains Jan’s experience of seeing a “red traffic light.” (In the Thermal Model, an experience occurs while a phase *is being established* in a Neuronal Group. However, phases can also be *confirmed* and experienced anew through a similar but milder process that is like tapping a meter to see whether it returns to the same reading after the tapping causes it to move.)



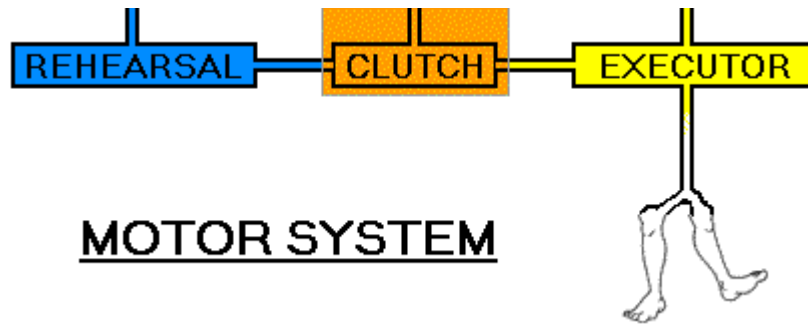
In the second state, when the Clutch is in *the Neuronal Critical State*, as in the image below, the Clutch is absorbed into Consciousness (the orange state) and there is a suspension of the Clutch’s capacity to transmit energy or signals through a pipeline. The two other Neuronal Group Assemblies, separated by the Clutch, can no longer engage each other. The image shows Stabilizor briefly maintaining a former state even though Now_Image has changed.

The Model supposes that the constraints simultaneously imposed on Visual Clutch by the red dynamic pattern and the green dynamic pattern results in an increase of activity and energy that drives the Visual Clutch into the Neuronal Critical State. As a result, there is no connection between Stabilizer and Now_Image. Making and breaking that connection is the function of the Visual Clutch. Below, I discuss the nature of the Neuronal Critical State that makes this work.

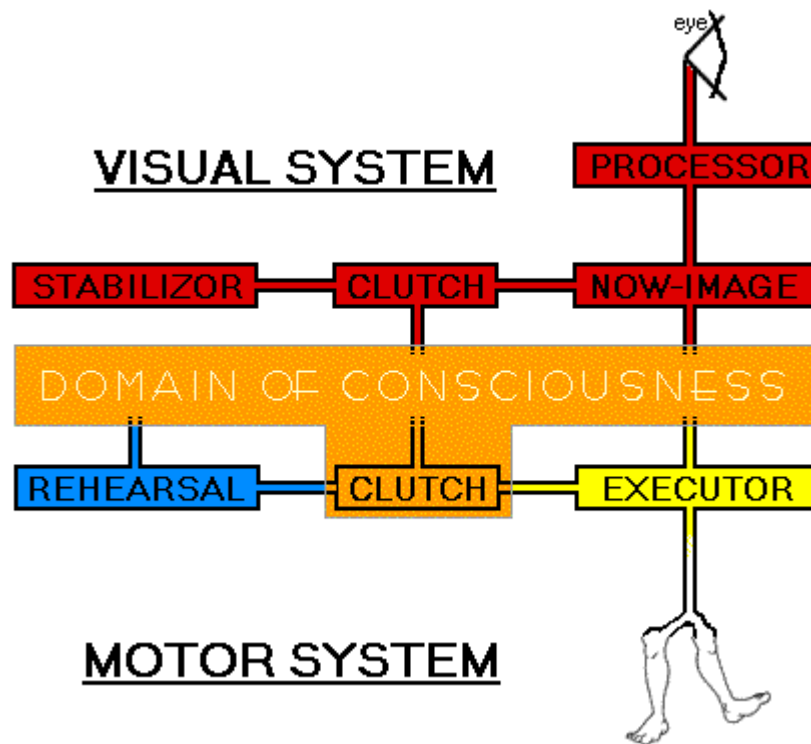


The Model of Jan's Motor System while Waiting at the Traffic Light is shown in the image below. It shows three simultaneous dynamic patterns, each resident in a Neuronal Group Assembly. The Assemblies are potentially available to be connected, but no signaling, energy transmission etc. is occurring at this time.

1. A dynamic pattern, "waiting" identified by "yellow" -- left foot pressing on automobile clutch pedal and right foot pressing on brake pedal -- is being executed in Executor. Executor is the part of the Motor System that is actually activating muscles. According to the Model, Consciousness is not required to maintain this dynamic pattern in Executor but it may be confirmed from time to time.
2. A dynamic pattern, "driving" identified by "blue" -- shift right foot to accelerator and press accelerator in coordination with release of clutch pedal by left foot -- is in Rehearsal. A dynamic pattern in Rehearsal is not activating muscles but can, when discharged into Executor, establish a dynamic pattern in Executor. According to the Model, Consciousness is not required to maintain this dynamic pattern in Rehearsal but it may be confirmed from time to time.
3. The Motor Clutch is in the *Neuronal Critical State* similar to that of the Visual Clutch discussed above. In the state imaged, Rehearsal is disconnected from Executor.



In the image below, Jan's Visual System and Motor System have been combined in a system inside Jan's skull along with Consciousness.



In the Model, Consciousness is identified as a special dynamic pattern called the Neuronal Critical State. The Neuronal Critical State is a state that *absorbs* some Neuronal Groups and Neuronal Group Assemblies. When absorbed into Consciousness, a Neuronal Group loses its separate identity. Neuronal Groups absorbed into the Neuronal Critical State act “as if” they were aggregated in a single Neuronal Group.

The Neuronal Critical State is based on properties of the *Thermodynamic Critical State*

that appear applicable to brains. Using the constructional concepts of § 5 of the Introduction, the Neuronal Critical State is a virtual concept based on the Thermodynamic Critical State. That is, I take appropriate features from the Thermodynamic Critical State as features of the Neuronal Critical State and I suppose that the Neuronal Critical State has other features that can be stated and developed.

A Critical State, whether thermodynamic or neuronal, is an Ideal. The chief properties of the Ideal Neuronal Critical State are set forth below and supported by more detailed statements elsewhere, e.g., the Introduction to the *Researches in Personal Freedom*, section 4, article 17.

1. When a Neuronal Group Assembly enters into the Neuronal Critical State, the existing dynamic pattern is disrupted. The Neuronal Critical State supports no dynamic pattern particular to a Neuronal Group Assembly but only the general Neuronal Critical State dynamic pattern and whatever else may be involved in that dynamic pattern, including matters that may be real and unknowable as discussed in § 3 of the Introduction.

“Whatever else” may include the ineluctable stuff of subjective selfhood. I respect such possibilities but I do not ground any suppositions on them. As an aid of thought and a guard against inappropriate speculation, I prefer to think of the Neuronal Critical State as a kind of “saturated buzzing,” which is buzzing to the point of drowning out everything else. In terms applicable to technical concepts, I presume that the Neuronal Critical State has no apparent ordering in space and/or time. More: that no ordering in space and/or time is possible. The Neuronal Critical State is a state that *excludes* such ordering, even a state that would annihilate any such ordering that should by chance appear.

2. When a Neuronal Group Assembly leaves the Neuronal Critical State, it “relaxes” (using the word in a technical sense) into a dynamic pattern that is characteristic of the that Neuronal Group Assembly and that conforms to constraints imposed by other Neuronal Group Assemblies that are involved in activity with the subject Neuronal Group Assembly.

3. By entering into and leaving the Neuronal Critical State in a cyclical way, a Neuronal Group Assembly “erases” and “rewrites” its activity. In an alternative view, Consciousness erases a dynamical pattern and then selects a new pattern, e.g., a new dynamical pattern that conforms to constraints imposed by other Neuronal Groups, perhaps even by Reality.

4. The Neuronal Critical State is an *absorbing* (or “binding”) state. If there are two Neuronal Groups that are directly connected and if each is in the Neuronal Critical State, the functional result is “the same” as if there was a *single* Neuronal Group in the Neuronal Critical State. An Assembly of Neuronal Groups in the Neuronal Critical State is “the same” as a single Neuronal Group in the Neuronal Critical State; and this is true of

all Assemblies of Neuronal Groups in the Neuronal Critical State even though it is, in general, not true when Neuronal Groups are not in the Neuronal Critical State.

In the Model, as a general principle, Neuronal Group Assemblies cannot assemble with one another; and there is no comprehensive way to organize dynamic patterns in diverse Neuronal Group Assemblies on a permanent, evolving basis. (There are particular classes of dynamic patterns that can be so organized; and their generation and study is a most important area of investigation for Idealized Brains akin to a Truesdell-inspired investigation or mapping of an equation of state by an Ideal Heat Engine.) A Structural Engine has the capacity to organize disparate dynamic patterns, but on an *ad hoc* basis in an episodic and periodic way.

My speculations on “how” the Neuronal Critical State works as an absorbing state is based in part on physics and in part on engineering.

First the physics. A chief principle of the Thermodynamic Critical State is stated in technical language as follows: as a system enters into the critical state, the correlation length of fluctuations grows unbounded (towards infinity). This means that a “jiggle” at one place in the system is “felt” at another, distant place with the same power as if the jiggle were occurring at the nearest neighboring place in the system.

Generalizing this principle (infinite correlation length of fluctuations) to neurons is straightforward. When neurons in a Neuronal Group are involved in the Neuronal Critical State, each neuron is equivalent to a “nearest neighbor” with respect to each other neuron in the Group in terms of fluctuation correlations. During Neuronal activity that is other than in the Critical State there is a *pulsing* of something I call Virtual Energy that is channeled through a Neuronal Group like a pulse of blood through tissue or a bolus of food in the digestive tract. No such pulsing can occur when the Neuronal Group is in the Neuronal Critical State because the neurons can’t sustain a direction or a waveform.

The same thing happens to two Neuronal Groups sequentially connected in a Neuronal Group Assembly that is sustaining a cyclical, repetitive dynamic pattern. If two Neuronal Groups are each in the Neuronal Critical State and if the groups are reciprocally interconnected, then a neuron in one Neuronal Group is like a “nearest neighbor” to every neuron in the other Neuronal Group and the two Groups are, in effect, a single Group.

Second the engineering. The Thermal Model of Brains supposes that Neuronal Groups interact so that *Critical State sets the zero*. That is, the Neuronal Critical State, common to many Neuronal Groups, is a state from which small departures can be coordinated among diverse Neuronal Groups that are otherwise independent. In Modeling such an organization, there is a quantity of common interconversion (Virtual Energy) and the basis of interconversion is a common “zero” that is identified to the Neuronal Critical State. Any sustained cyclical, repetitive dynamic pattern is characterized by a Virtual Energy less than 0. Some cyclical, repetitive dynamic patterns may be sustained with

Virtual Energy incrementally less than 0 and such patterns may appear in diverse systems. It is straightforward to suppose *that* Consciousness, using neurons in the Neuronal Critical State, has a capacity to coordinate the establishment of selected patterns in the diverse systems, even though I abstain from speculating about *how* this might accomplished.

There are questions about the processes for “setting the zero.” One might speculate, for example, that necessary interactions occur during sleep. The biological purpose of such interaction would be to simulate activity needed to “adjust” for most efficient coordination of Critical State absorptions and detachments and some sort of Consciousness would attend the simulations.

5. The Neuronal Critical State is a state high in “energy” or Virtual Energy. The Neuronal Critical State is *just slightly more energetic* than the *most energetic phase* or dynamic pattern that a Neuronal Group Assembly can sustain.

(Correspondingly, in a liquid-gas system, the Thermodynamic Critical State is just above the state of highest energy that can support a liquid phase. E.g., in H₂O, the Thermodynamic Critical State is the state incrementally hotter than the highest temperature at which liquid water can be produced by high pressure. Conversely, stable states in equilibrium can come into being when energy is reduced to slightly less than that that sustains the Thermodynamic Critical State. In water, only a tiny reduction in temperature is needed for strongly stable states to emerge. Technically, the latent energy of vaporization falls very rapidly to zero as the temperature approaches the critical temperature along the line defined by liquid-gas equilibrium coexistence.)

6. The Neuronal Critical State is simultaneously a state of *confusion* and of *readiness*.

7. The Neuronal Critical State is a *universal* state, “the same” for all persons and all times, with “the same” physical properties for all neuronal groups and neuronal group assemblies involved in that state and “the same” in several interpretative forms and on multiple levels of size, namely, on the scale of the neuron, the Neuronal Group Assembly and the person. This property is based on established “universal” properties of the Thermodynamic Critical State.

8. The Thermodynamic Critical State has *unique, weird, lovely properties* that are *mathematically intractable*, except for “*a tiny edge*” developed through advanced physics. I extend these properties and what knowledge we have to the Neuronal Critical State I suppose to exist in brains. I suppose that that brains – active and more complex than magnets, gases and such simple thermodynamic systems – enhance these properties. These observations are consistent with and support a major premise of the Researches that *detailed understanding of conscious activity is beyond human intelligence*.

In images of the Structural Engine, such as the preceding image, the Model supposes that the Visual System and the Motor System are each independent but connected to one another though parts of Jan's brains that are absorbed into Consciousness.

The statement of the Thermal Model includes a clear definition of the boundary or surface (sometimes called *the control surface*) around those Neuronal Group Assemblies that are absorbed into the Neuronal Critical State. That is, the Model depends on imagining a *closed and extremely thin* surface inside Jan's brains. Some Neuronal Group Assemblies are inside the surface and some outside and the division is supposed to be complete and exact. Under this definition, the control surface inside Jan's brains does not cut "through" any Neuronal Group Assembly, but only "between" Neuronal Group Assemblies.

Neuronal Group Assemblies inside the control surface are all absorbed into the Neuronal Critical State, but may, like Motor Clutch, be subject to detachment. Neuronal Group Assemblies outside the surface but adjacent to the surface are not in the Neuronal Critical State, but may, like Visual Clutch, be subject to being driven into the Neuronal Critical State and absorbed into Consciousness.

The surface *partitions* Jan's brains into distinct regions or domains. In one domain, there is a single general, absorbent dynamic pattern (Neuronal Critical State). At all times, e.g., before and after any absorption and before and after any detachment, Consciousness is a unity defined by the closed surface. Inside the closed surface is the *Domain of Consciousness* and all neuronal groups in the Domain of Consciousness are in the Neuronal Critical State.

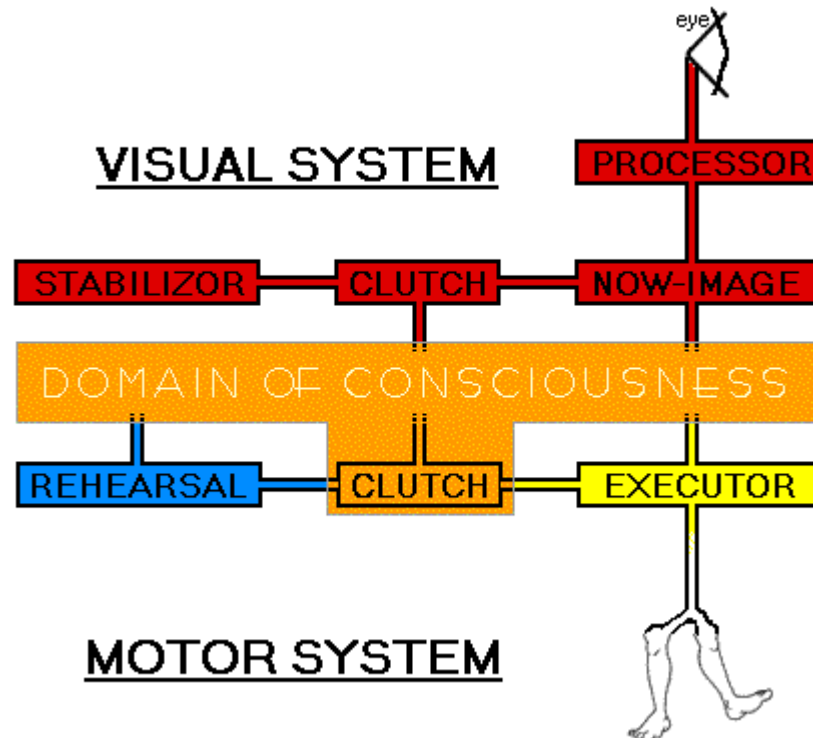
The Thermal Model has a "strict" definitional core and a "looser" general description (corresponding to "strict abstinence" and "licentious abstinence" in speculating about matters real and unknowable, as discussed in § 5 of the Introduction).

Strictly, the Thermal Model allows for definition only when the control surface surrounding the Domain of Consciousness is stationary. The stationary state may be momentary, as when a stone thrown straight up is momentarily stationary before it starts to descend. A looser description allows for some speculation about activity between stationary states.

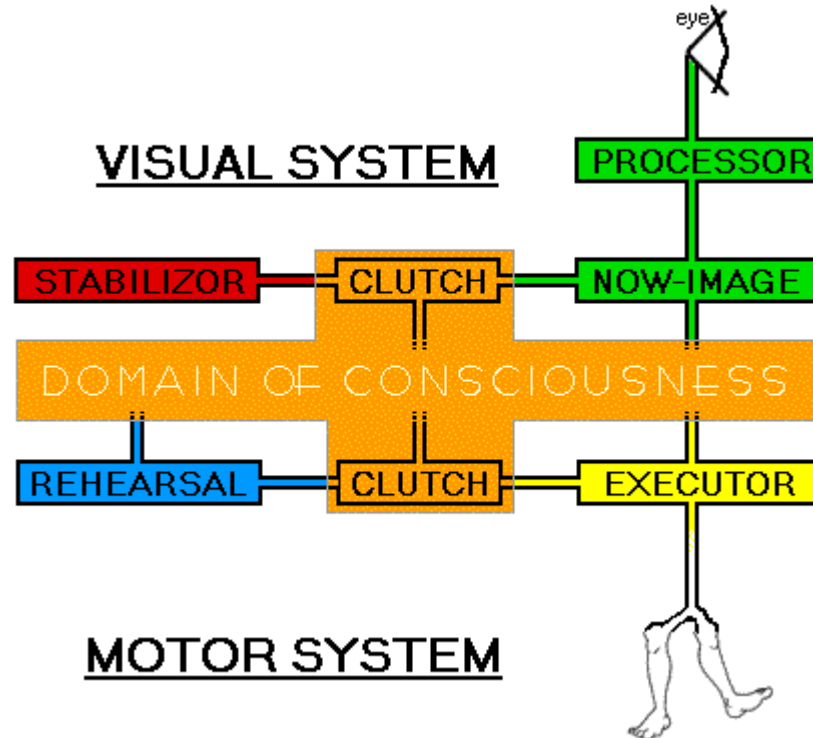
OPERATION OF THE STRUCTURAL ENGINE

“JAN WAITING AT THE TRAFFIC LIGHT”

1. Begin with Jan Waiting at the Traffic Light as previously described. Jan sees that the traffic light is Red. She is executing the Wait dynamic pattern. Start-to-drive is in Rehearsal.



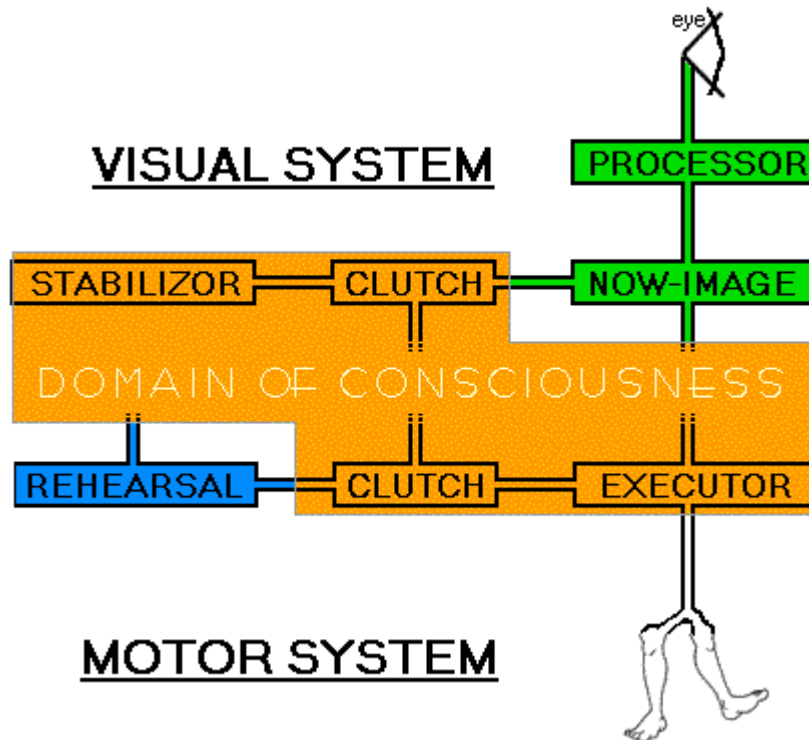
2. The traffic light turns green. The simultaneous presence of Red and Green in the Visual Clutch results in an Energy increase sufficient for Visual Clutch to enter into the Neuronal Critical State. The Visual Clutch is absorbed into Consciousness and the pipeline connection between Stabilizor and Now-Image is interrupted. Stabilizor is momentarily maintaining Red.



3. The Domain of Consciousness, its enlargement triggered by the change in the traffic light, grows even larger. Strictly, the Model states *nothing* about what is going on *inside the Domain of Consciousness*. Speculation suggests that there are “heating waves” that pass through Neuronal Group Assemblies absorbed into Consciousness and these waves can account in a coarse way for enlargements of Consciousness into additional Neuronal Group Assemblies.

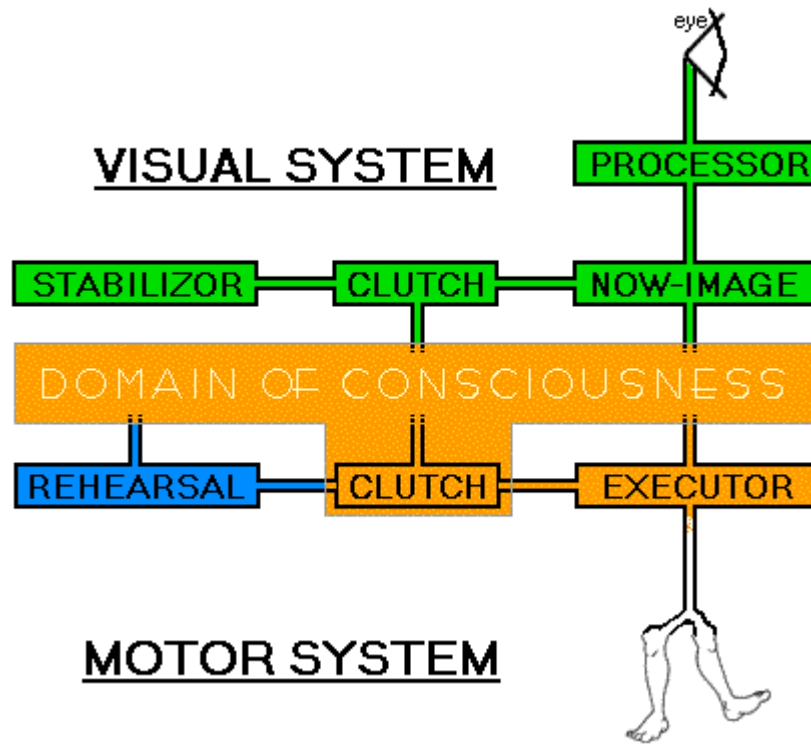
The enlargement of the Domain of Consciousness in this example proceeds as the Neuronal Critical State engulfs Stabilizor and Executor; and Stabilizor and Executor are driven out of the Waiting dynamic pattern and into the Neuronal Critical State, and thus absorbed into the Domain of Consciousness.

The result is a stationary state. Speculatively, this state is reached as the heating wave reaches its highest level and just before it begins to subside.

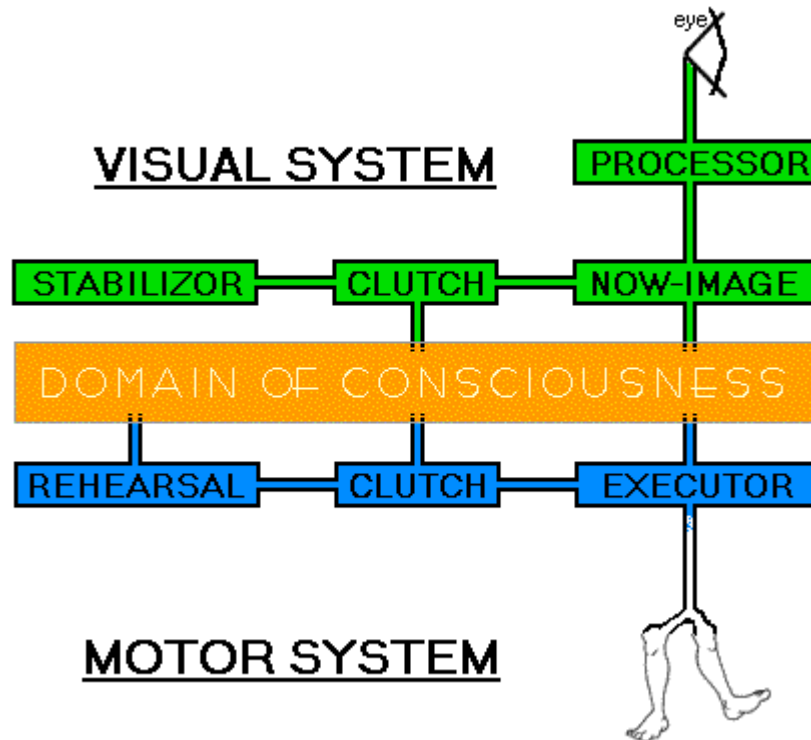


4. At the start of the next and most important part of the stroke of the Structural Engine, both the Visual Clutch and the Motor Clutch are absorbed into Domain of Consciousness as in the previous image. Detachment then occurs in two places. I speculate that the detachments are coordinated – and this is an important speculation – but the two detachments are shown here separately. The Thermal Model *abstains* from stating how the detachments take place or the order of the detachments. Licentiously, I indulge in speculation and suggest an order of detachments.

a. Visual Clutch detaches from Consciousness and relaxes into green, based on the existing presence of green in Now-Image. Green is mirrored and maintained in Stabilizor. Jan experiences green. (In the Thermal Model, the experience occurs during the relaxation and stabilization. That is, Jan’s experience of Green occurs *while* the Green dynamic pattern is being formed.)



b4. Motor Clutch and Executor detach from the Domain of Consciousness and relax into Drive, based on the existing presence of Drive in Rehearsal. Jan starts to drive.



I speculate that *both* sets of detachments (i.e., both Visual and Motor) occur in connection with a “cooling wave” that passes through the Domain of Consciousness. Using concepts borrowed from metallurgy (e.g., “quenching” and “nucleation”), I suggest that, during such a cooling wave, dynamic patterns can arise in a fragmentary and flickering way outside of but near the surface of Domain of Consciousness and that cooling can culminate, at a particular place, in detachment of a Neuronal Group Assembly from Domain of Consciousness followed by relaxation into a particular dynamic pattern characteristic of that Assembly.

In a further, important speculation, I suppose that under some circumstances and constraints, Consciousness has a capacity to *select* the dynamic pattern into which the detached Neuronal Group Assembly relaxes. [For example, I could suppose that Consciousness selects the “next” dynamic pattern into which Rehearsal shall relax, as shown at the conclusion of this document.] This selection is apparently what “free will” is about. I suppose that such a selection is coordinated through Consciousness to “fit” with other selections. My suppositions do not include a statement about “how” the selection is made. I suppose that my limited intelligence that generates defective products (Introduction, § 4) cannot state principles about “how” selection is accomplished. I abstain from suggesting such principles. This is abstinence to which I hold.

In the Model of Jan Waiting at the Traffic Light, perceptions (redlight and greenlight) and muscular activities (waiting and driving) are *products of consciousness* but generated when there is detachment from the Domain of Consciousness. That is, in the Thermal Model, production of perceptions and muscular actions occurs when Neuronal Group Assemblies are detached from the Domain of Consciousness and relax from the Neuronal Critical State. This applies to greenlight in the same way as driving. What is most important is that *products of consciousness are produced in combinations and these combinations can become structured objects*. In the example “Jan waiting at the traffic light,” the structures are: (1) redlight-waiting (2) greenlight-driving. This is one of the simplest structures imaginable.

The Structural Engine thus produces “events” that are combinations of “redlight-waiting” and “greenlight-driving.” The **combining** of the **perception** and the **action** is what “Jan waiting at the traffic light” is all about and I say that the *Structural Engine generates structural events*. A structural event, I suggest, is like a “stitch in the tapestry of experience” and the stitch, the *combination*, is the basic element both in experience and in neuronal activity. The Thermal Model does not state all the details of how that combination comes into being, but the Structural Engine can – and does – track some the process.

5.=>1. As a formal conclusion to this example, I suppose that Motor Clutch is absorbed back into Consciousness and the system moves toward a renewed state of *readiness*. I also suppose that an additional stroke of the Structural Engine generates a new dynamic

pattern in Rehearsal, but I provide no specification. Otherwise, at the conclusion, things in Jan's brains are much as they were before the traffic light changed. Of course, new dynamic patterns have replaced the former patterns. And Jan is now driving, a welcome change from waiting. Through such cyclical action, a Structural Engine engages Reality.

