BICA2014 Three Papers

Muneo Kitajima & Makoto Toyota

- **Paper 15**
  - *Hierarchical structure of human action selection – An update of Newell's time scale of human action*
- **Paper 16**
  - *Topological considerations of memory structure*
- **Paper 18**
  - *The role of consciousness in memorization: Asymmetric functioning of consciousness in memory encoding and decoding*

Outline of the Talk

- **Part 1: The basis of the studies**
  - *NDHB-Model/RT on O-PDP*
    - NDHB-Model/RT : Nonlinear Dynamic Human Behavior Model with Realtime Constraints
    - O-PDP : Organic Parallel Distributed Processing
    - http://oberon.nagaokaut.ac.jp/ktjm/organic-self-consistent-field-theory/index.html
- **Part 2: BICA2014 papers**
  - *With the focus of their relationships with NDHB-Model/RT*

Part 1:
NDHB-Model/RT under O-PDP

History of the Project

- 2007 Cognitive Science:
  - *MSA: Maximum Satisfaction Architecture*
- 2008 Cognitive Science:
  - *BIH: Brain Information Hydrodynamics*
- 2008 Cognitive Science:
  - *SMT: Structured Meme Theory*

- 2011 BIT (Behaviour and Information Technology) journal paper:
  - *publish the base model that deals with parallel distributed processing*

Focus on "Memory System"

- Works background to fire necessary information for action selection by effective narrowing the active regions
- 2012 ICCM paper:
  - *a mechanism for overcoming the problem of synchronization caused by the differences in operation speeds in the pipelining process in the memory system*
- 2014 BICA paper 16 and 18:
  - *Paper 16 considers the mechanism of circular development of memory system*
  - *Paper 18 considers asymmetry of encoding process and decoding process*

Focus on "Action Selection"

- 2013 BICA journal paper:
  - *a whole model of action selection in dual process (Two Minds), that develops a parallel processing mechanism in patio-temporal bands*
- 2014 BICA paper 15:
  - *adds a parallel processing mechanism for whole body movements, that works under the constraints of body plan (skeleton structure)*

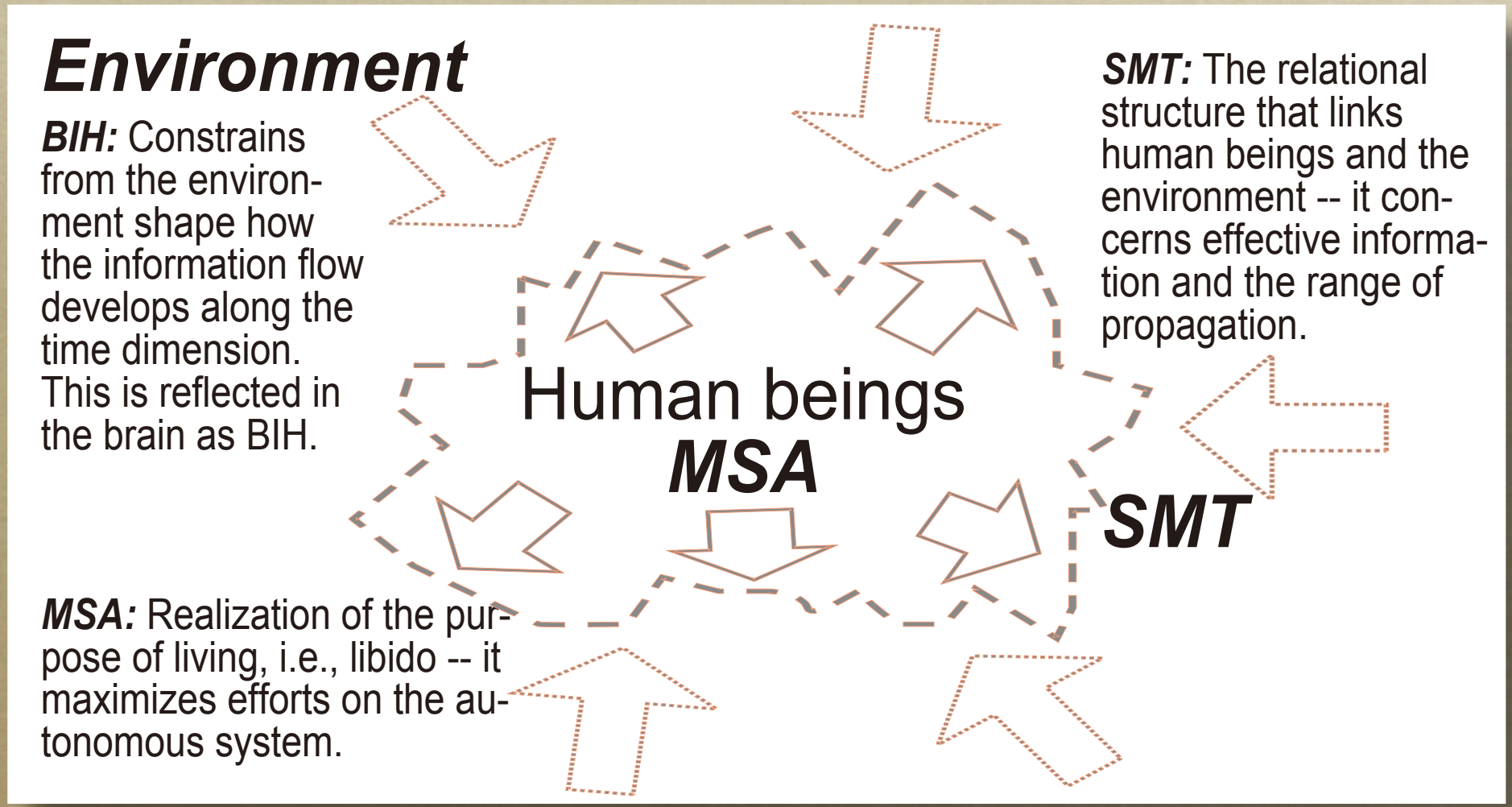
Development of a Survey Method CCE with the basis of NDHB-Model/RT

- 2012 IJQHT journal:
  - *International Journal Quality Assurance in Hospitality & Tourism*
  - *Understanding Tourists' In Situ Behavior: A Cognitive Chrono-Ethnography Study of Visitors to a Hot Spring Resort"*

O-SCFT:
Organic Self-Consistent Field Theory

- **SCFT: Self-Consistent Field Theory in Physics**
  - *In physics, self-consistent field theory studies the behavior of large and complex stochastic models by studying a simpler model.*
- **O-SCFT: "Organic" Self-Consistent Field Theory**
  - *Organic systems are comprised of human beings as their components. Any organic system can be represented as a model that considers a large number of interacting individual human beings which interact with each other.*
  - *The behavior of human-beings in the universe is quasi-stable, not stable but develop or evolve triggered by some fluctuations, a feature of dissipative system – a fluctuation of the system caused by an environmental change would trigger creation of a new order or catastrophe.*

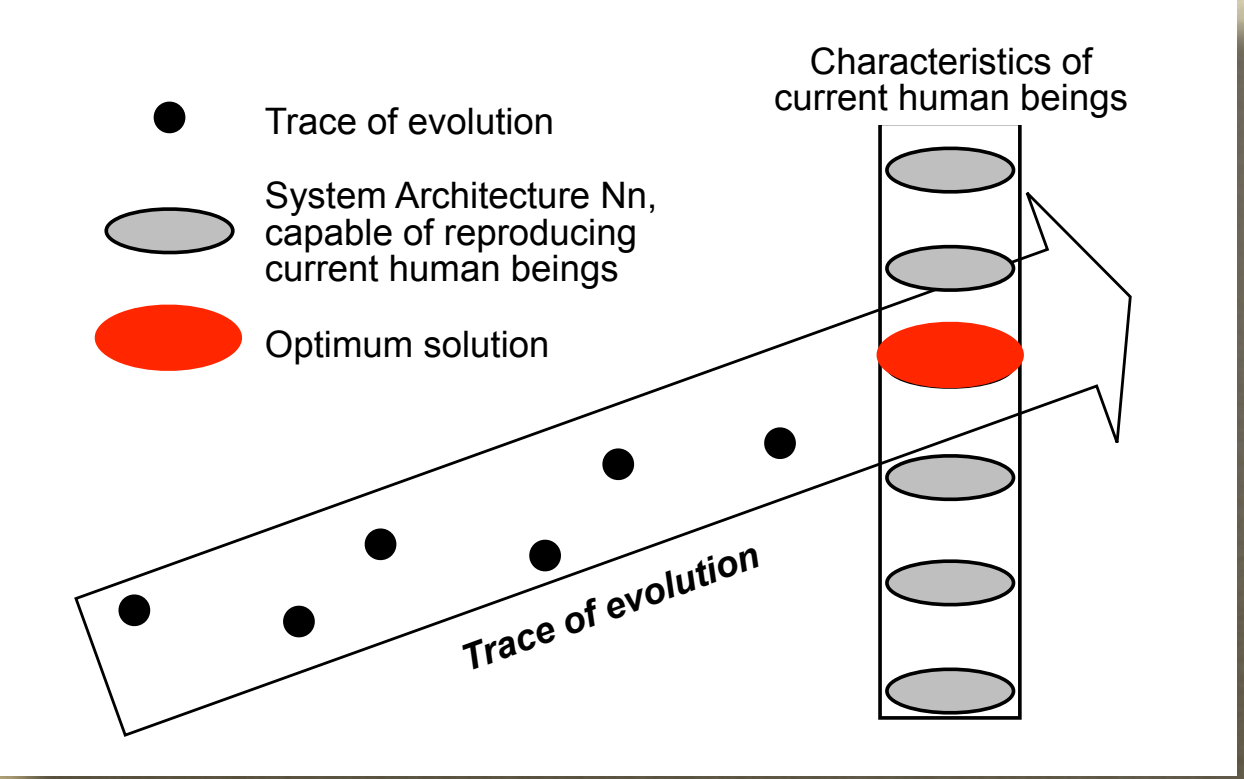
Human beings considered in O-SCFT: *MSA*, *BIH*, and *SMT*



O-PDP: "Organic" Parallel Distributed Processing

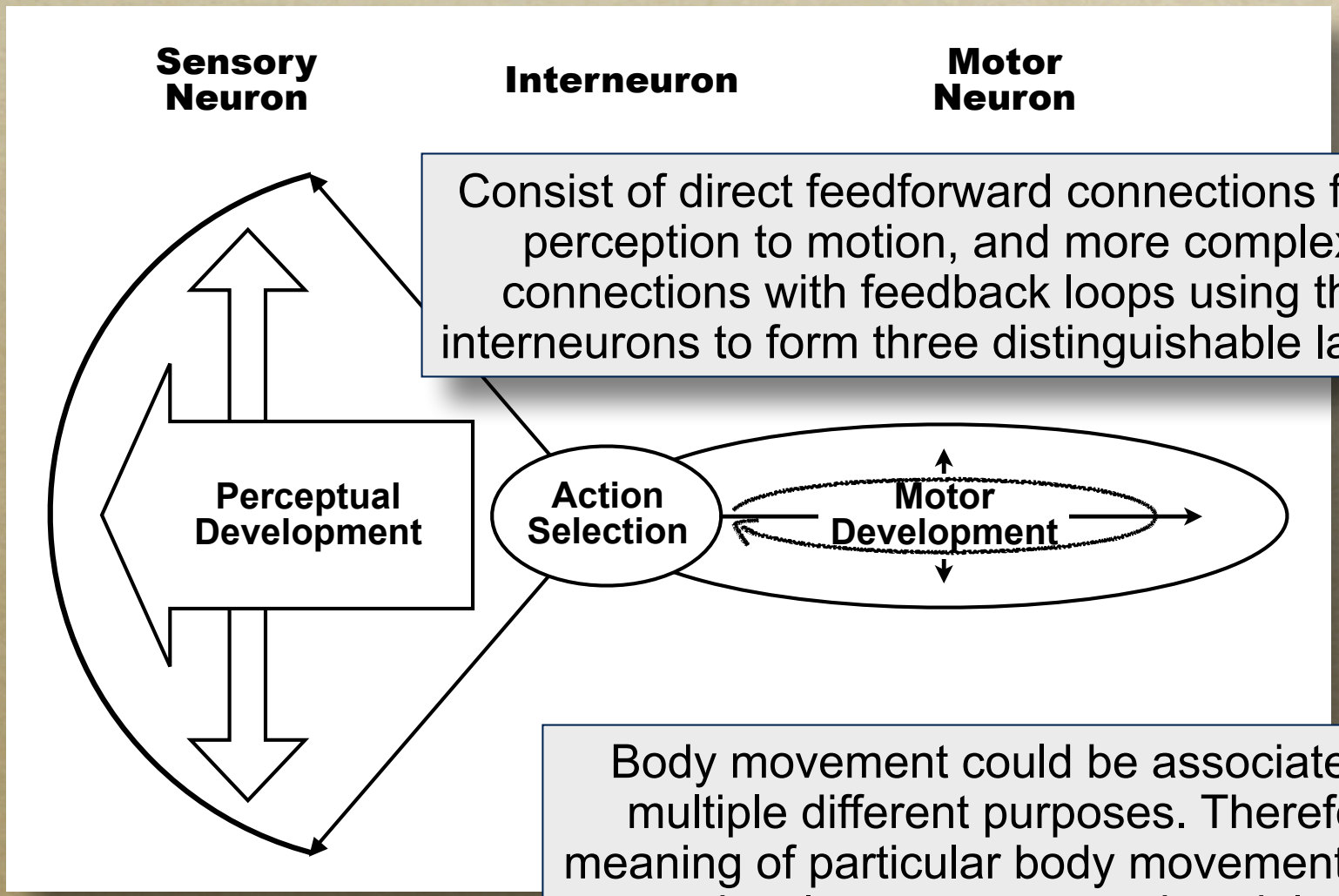
- **MSA, BIH, and SMT with the focus on information flow in the brain**
- **O-PDP develops cross-networks of neurons in the brain as it accumulates experience of interactions in the environment**
- **The neural network development process is circular**
  - *Meaning that any experience at a particular moment should reflect somehow the experience of the past interactions that have been recorded in the shape of current neural networks*
- **O-PDP system is organized evolutionally**
  - *Realized as a neural network system, including the brain, the spinal nerves, and the peripheral nerves*

Architecture Selection: The Guideline



It is quite reasonable to consider the one as the optimum solution that resides at the intersection of the trace of evolution of human beings and the system architectures that are capable of reproducing the characteristics of current human beings.

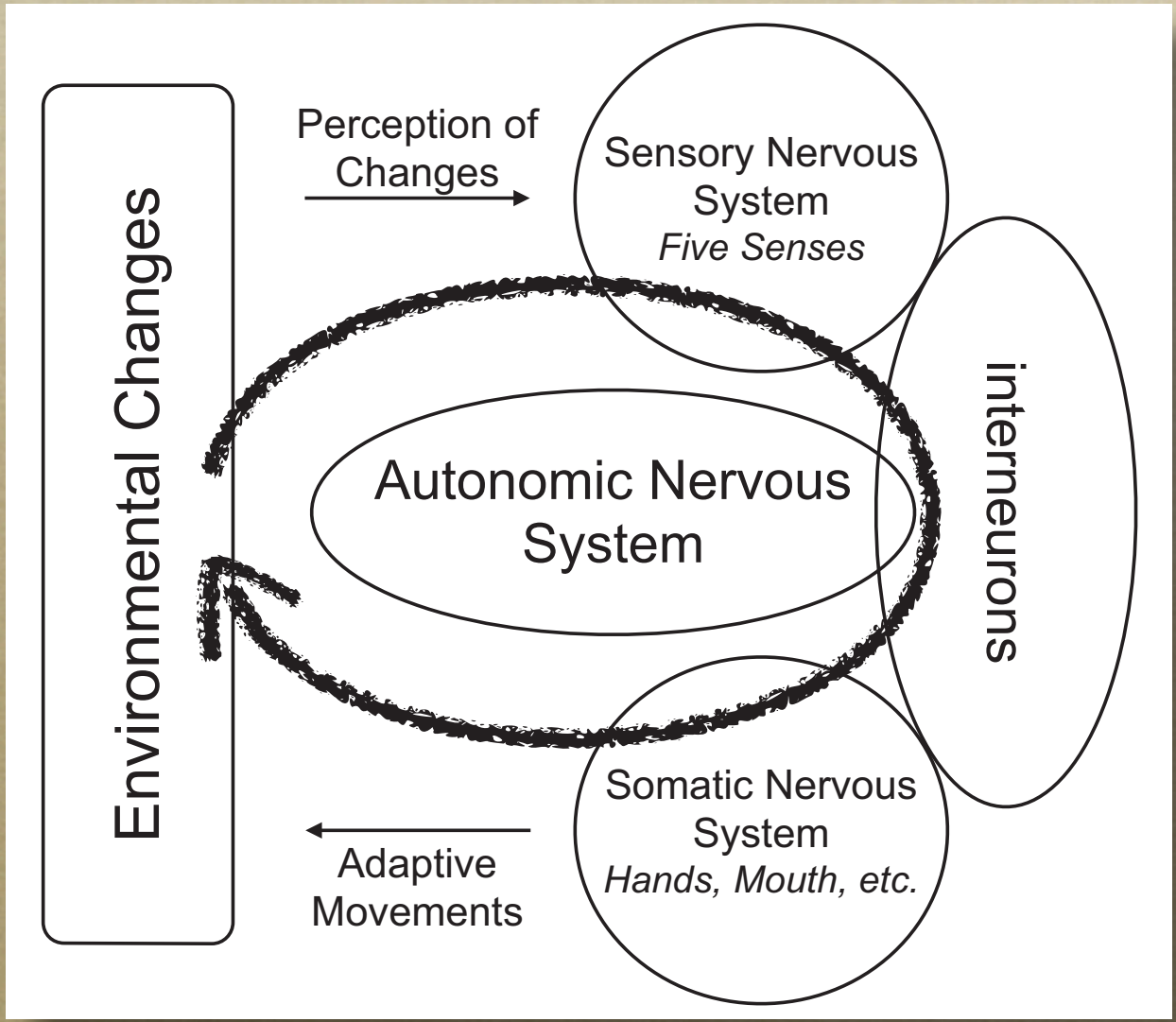
Evolutional Consideration:
Sensory-, Inter-, and Motor-Neurons



Consist of direct feedforward connections from perception to motion, and more complex connections with feedback loops using the interneurons to form three distinguishable layers

Body movement could be associated with multiple different purposes. Therefore, a meaning of particular body movement is given consciously as a compound social ecology.

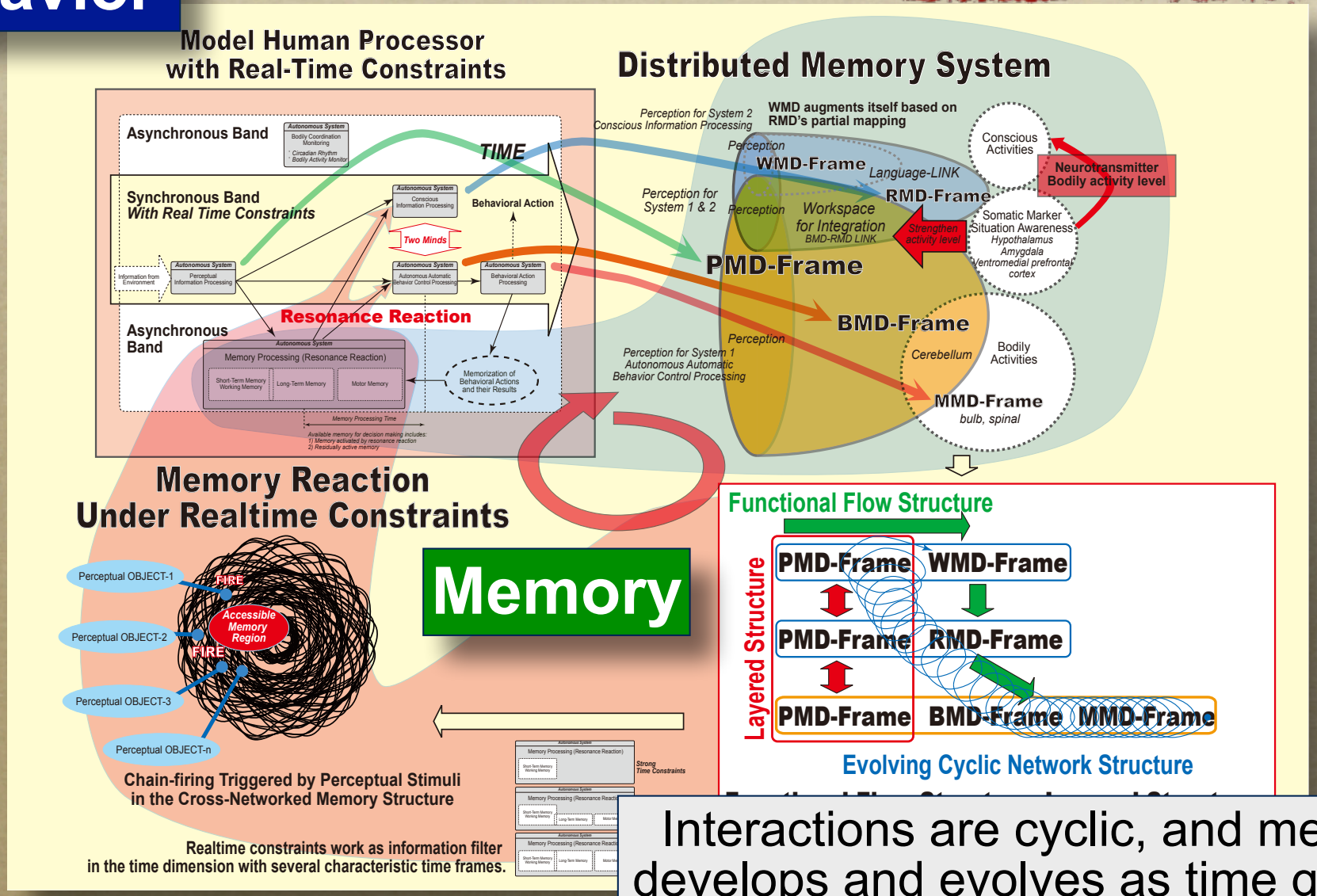
Continuous cyclic loop of perception and movement



NDHB-Model/RT

Nonlinear Dynamic Human Behavior Model with Realtime Constraints

Behavior



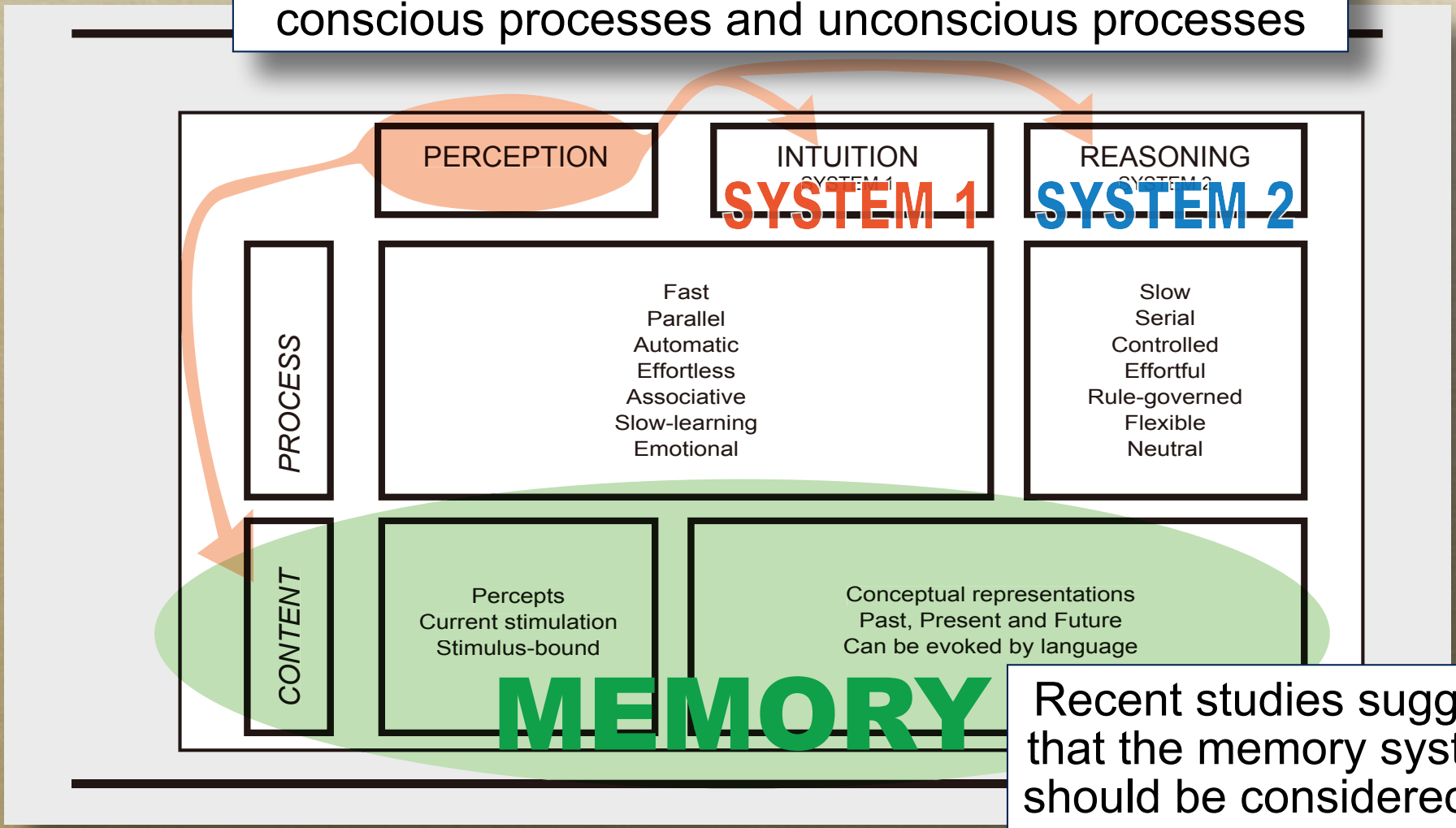
Interactions are cyclic, and memory develops and evolves as time goes by

MHP/RT: Model Human Processor with Realtime Constraints

An Implementation of NDHB-Model/RT with Two Minds and Autonomous Memory System with the focus of decision making and action selection

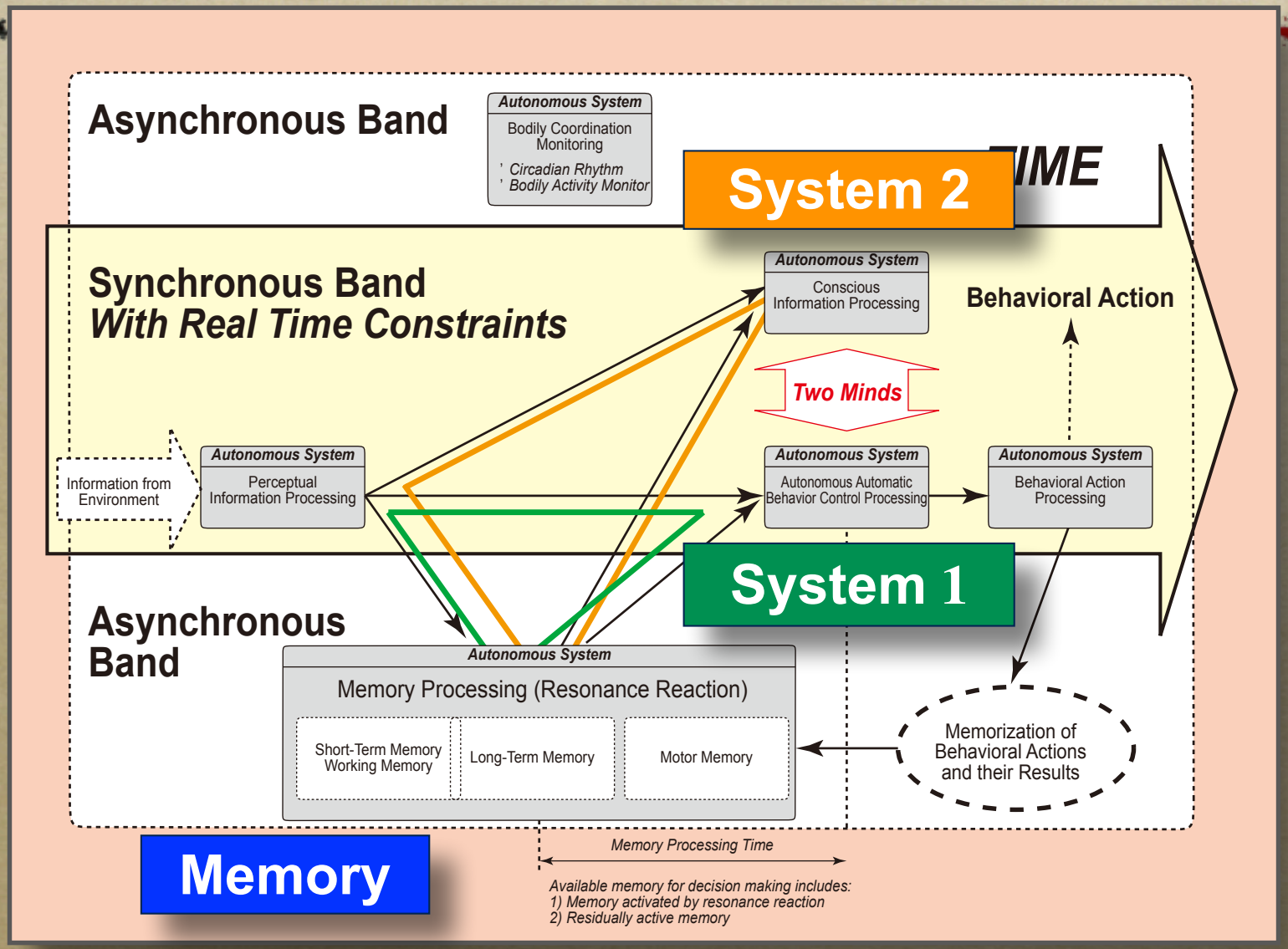
Two Minds (Kahneman, 2003) and Autonomous Memory

Processes under O-PDP can be divided into conscious processes and unconscious processes



Recent studies suggest that the memory system should be considered as autonomous.

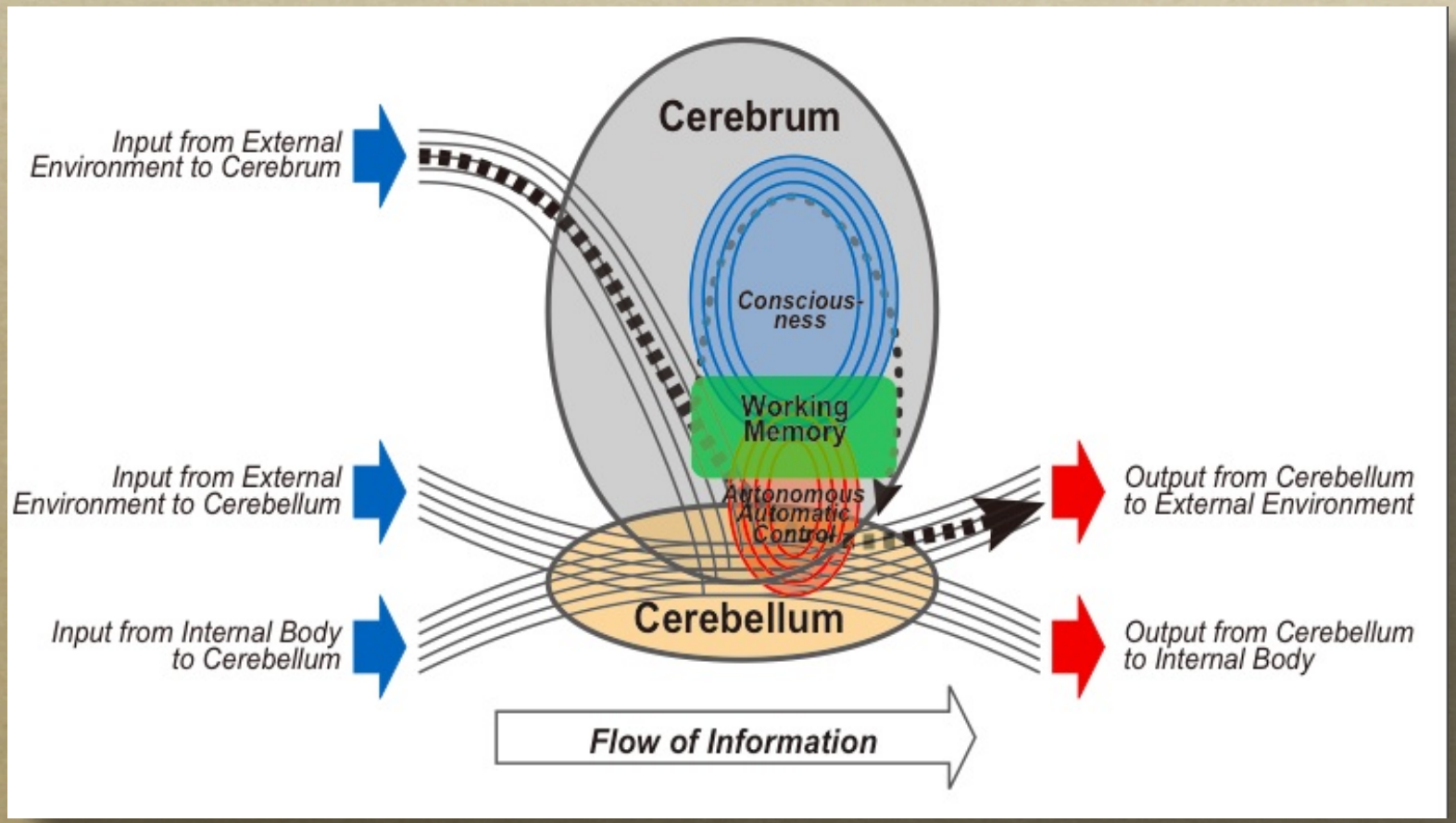
MHP/RT: Model Human Processor with Realtime Constraints



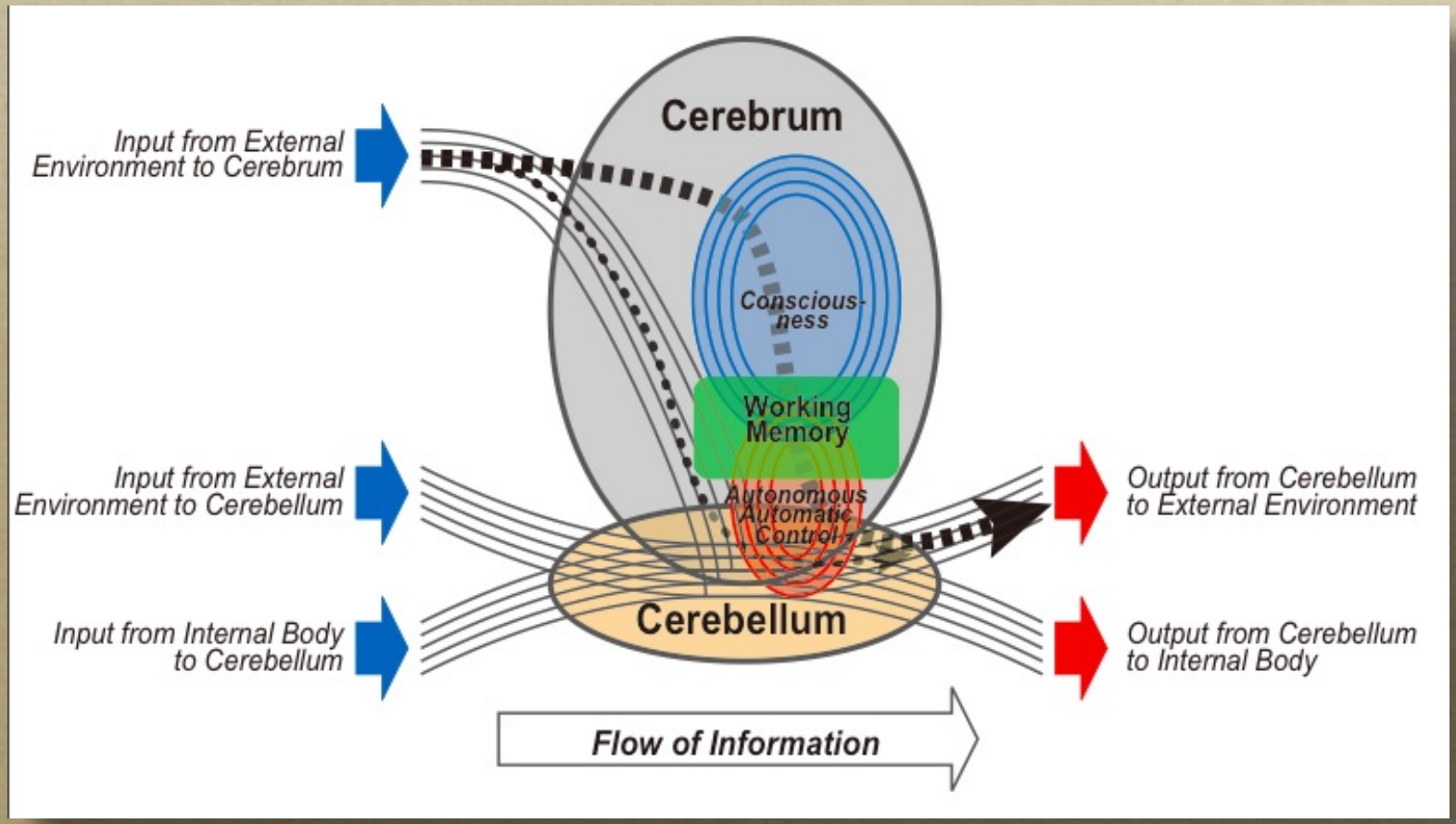
Four Operation Modes
"Which part of MHP/RT is working"

- **Depending on the situation, behavior is driven mainly by either System 1 or System 2**
- **When both systems work synchronously by sharing working memory:**
  - *Mode 1: System 1 driven*
  - *Mode 2: System 2 driven*
- **In some situations, however, both work asynchronously:**
  - *Mode 3, System 1 and System 2 work asynchronously, working memory may be shared weakly*
  - *Mode 4; System 1 and System 2 work independently, working memory may be used separately*

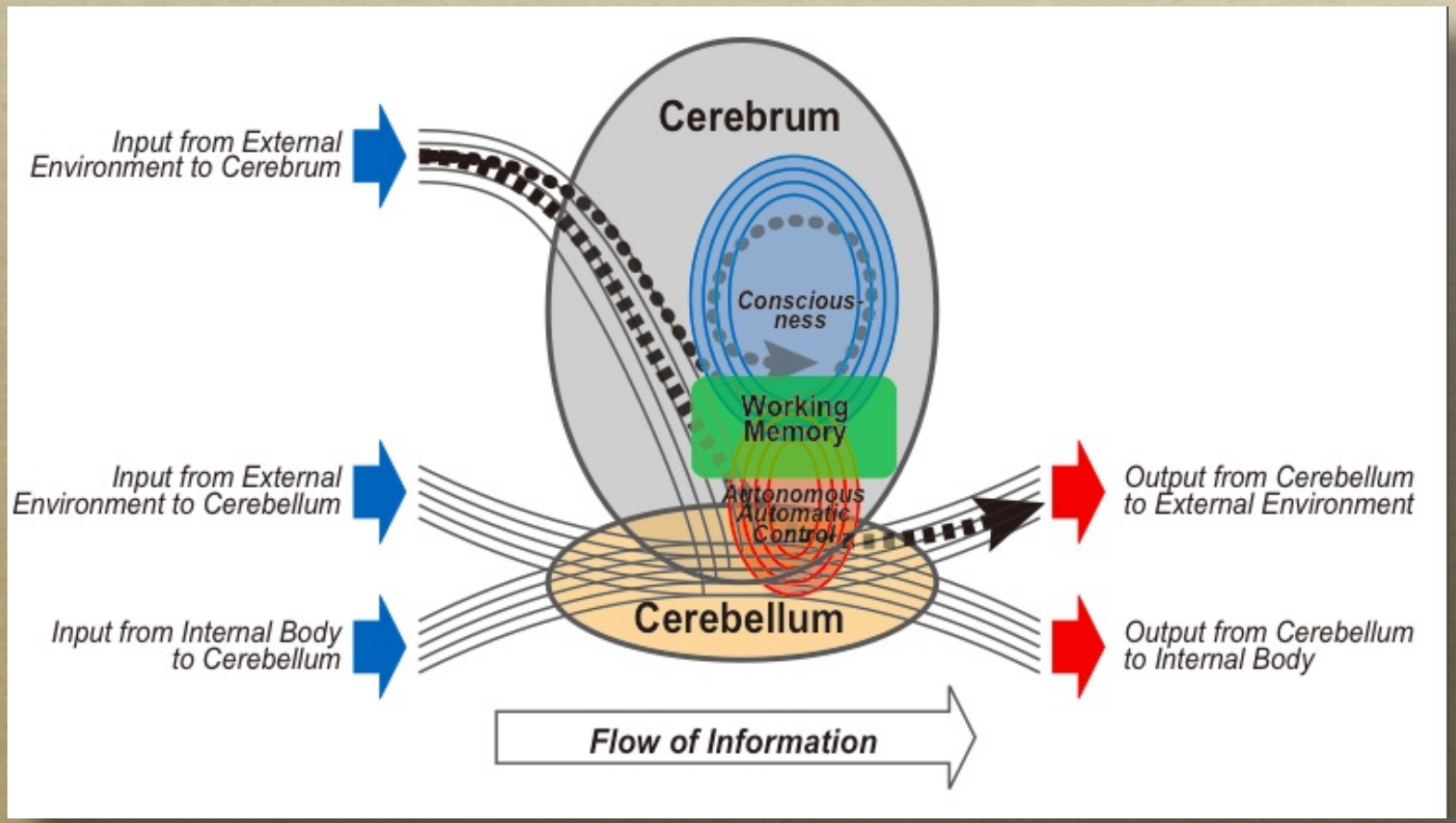
Four Operation Modes
Mode 1



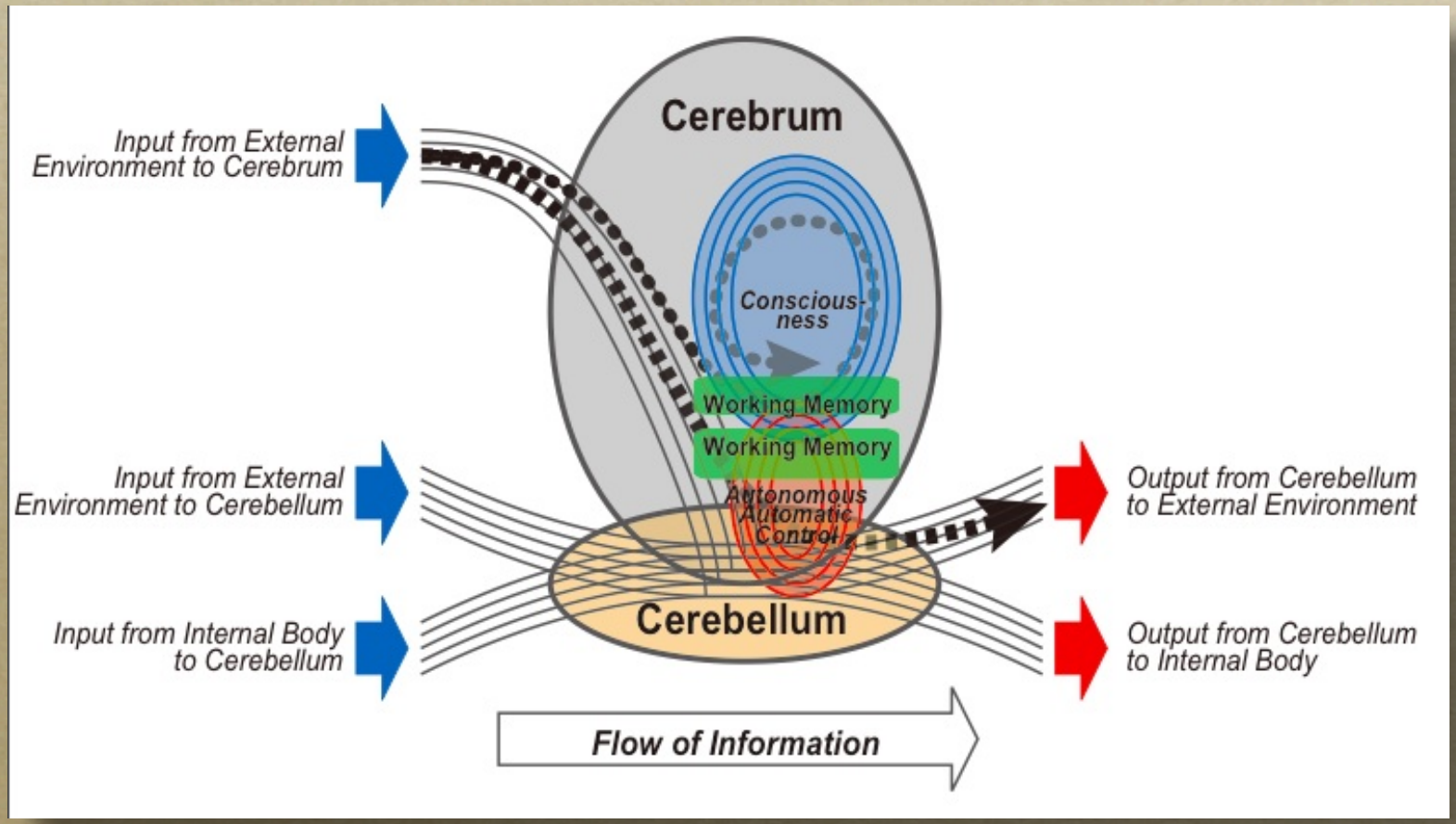
Four Operation Modes
Mode 2



Four Operation Modes
Mode 3



Four Operation Modes
Mode 4



Four Processing Modes
"How MHP/RT is working"

- **Decision making and action selection along the time dimension**
- ***Event* as the object for decision making and action selection**
  - *For MHP/RT, an event corresponds to a point on the time dimension where it can make decisions on selecting an action from the alternatives under a specific environmental condition.*
  - *The environment makes chaotic changes, and human beings, modeled by MHP/RT, are required to develop an adaptive system that is capable of dealing with a set of events that happen in such an environment.*

Four-Processes and Time Constraints

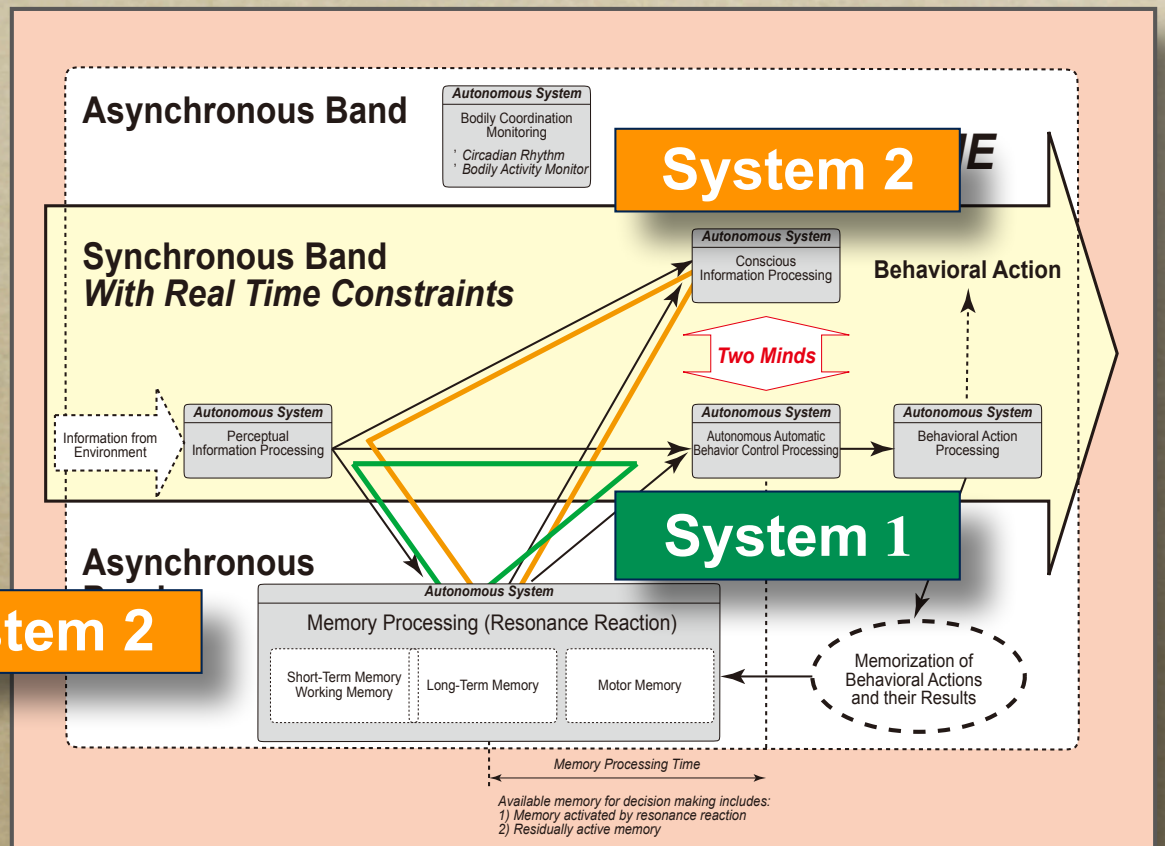
At a particular time before/ after the event, one engages in conscious processes and unconscious processes concerning the event.

Scale (sec)	Time Units	System	World (theory)	
10^{7}	months			Interactive Organic Activity
10^{6}	weeks			
10^{5}	days		SOCIAL BAND	
10^{4}	hours	Task		Habitual Organic Activity
10^{3}	10min	Task		
10^{2}	minutes	Task	RATIONAL BAND	
10^{1}	10sec	Unit Task		Habitual Bodily Activity
10^{0}	1sec	Operations		
10^{-1}	100ms	Deliberate Act	COGNITIVE BAND	
10^{-2}	10ms	Neural Circuit		Internal Activity
10^{-3}	1ms	Neuron		
10^{-4}	1 Hs	Organelle	BIOLOGICAL BAND	

Newell's Time Scale of Human Action

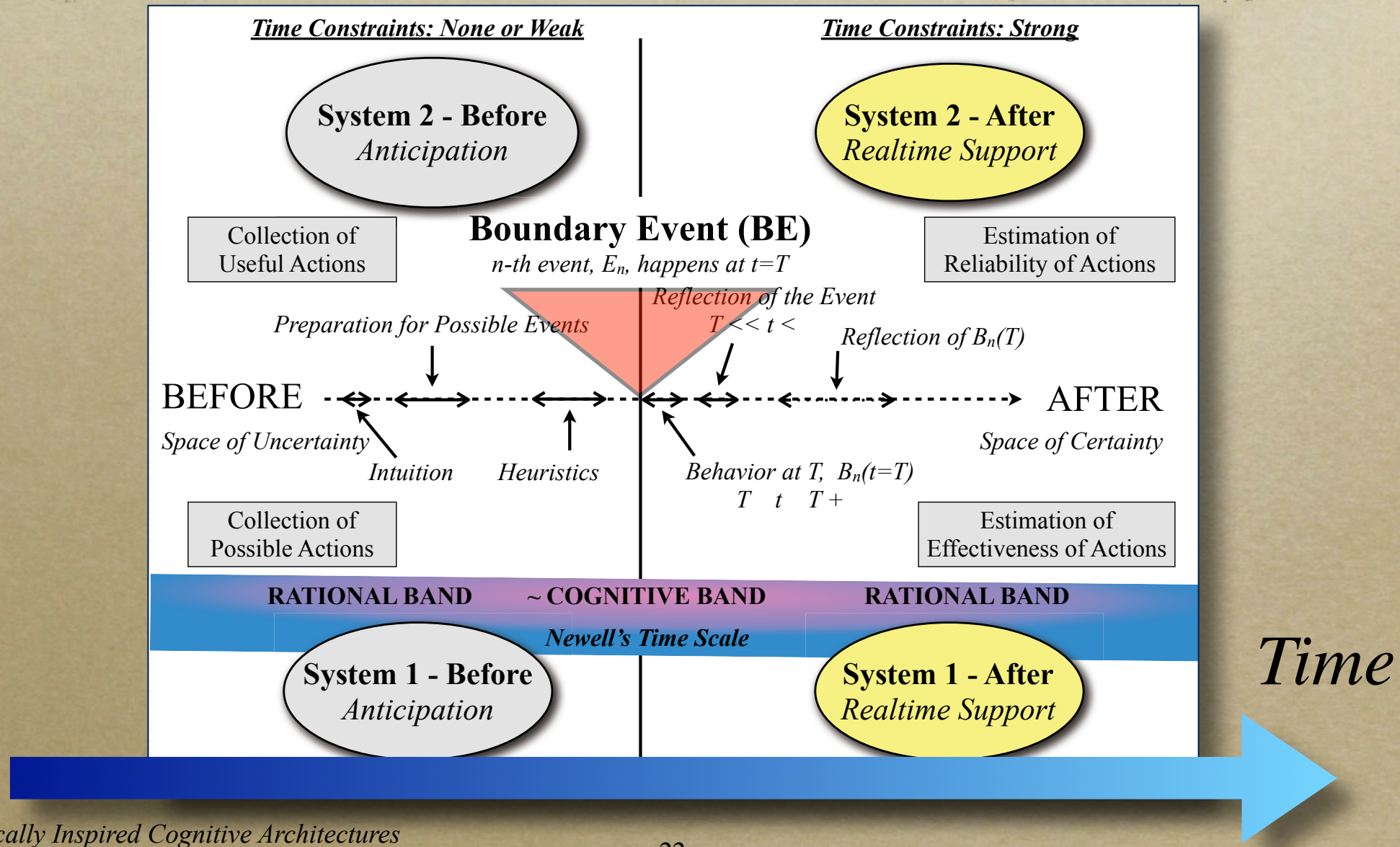
System 2

System 1

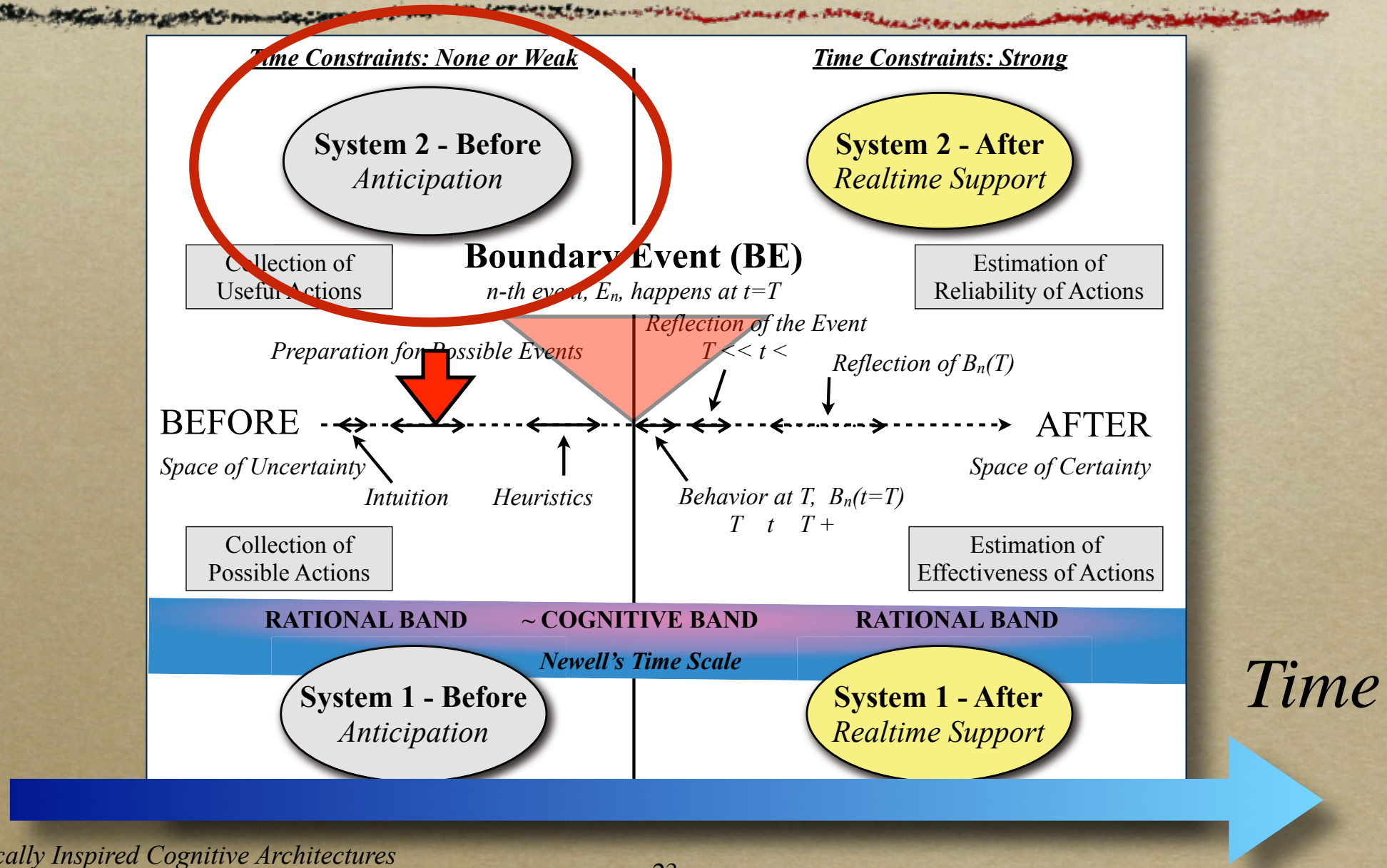


What one can do before and after the event is strongly constrained by the Newell's time scale of human action.

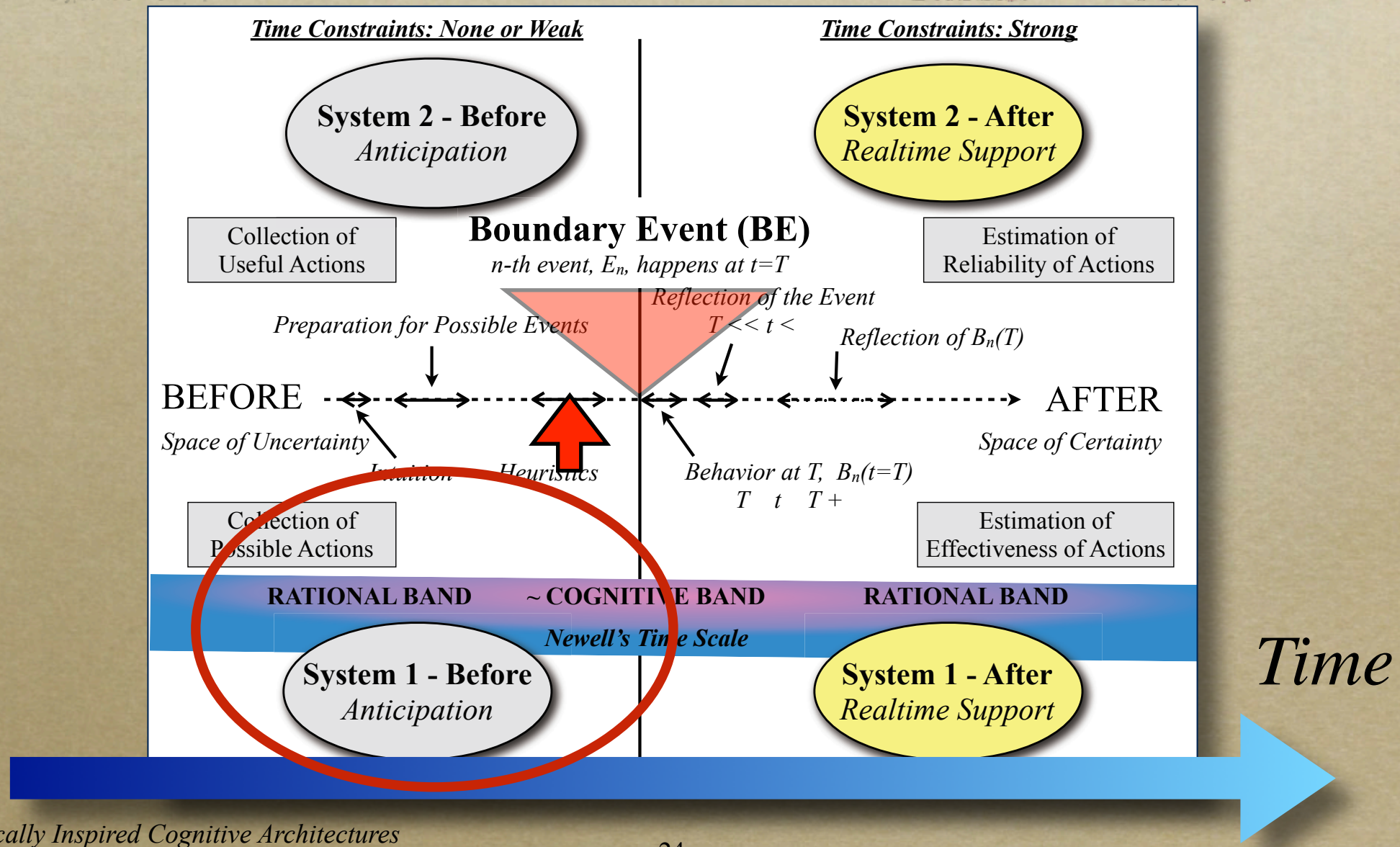
How the Four Processing Modes Work



How the Four Processing Modes Work



How the Four Processing Modes Work



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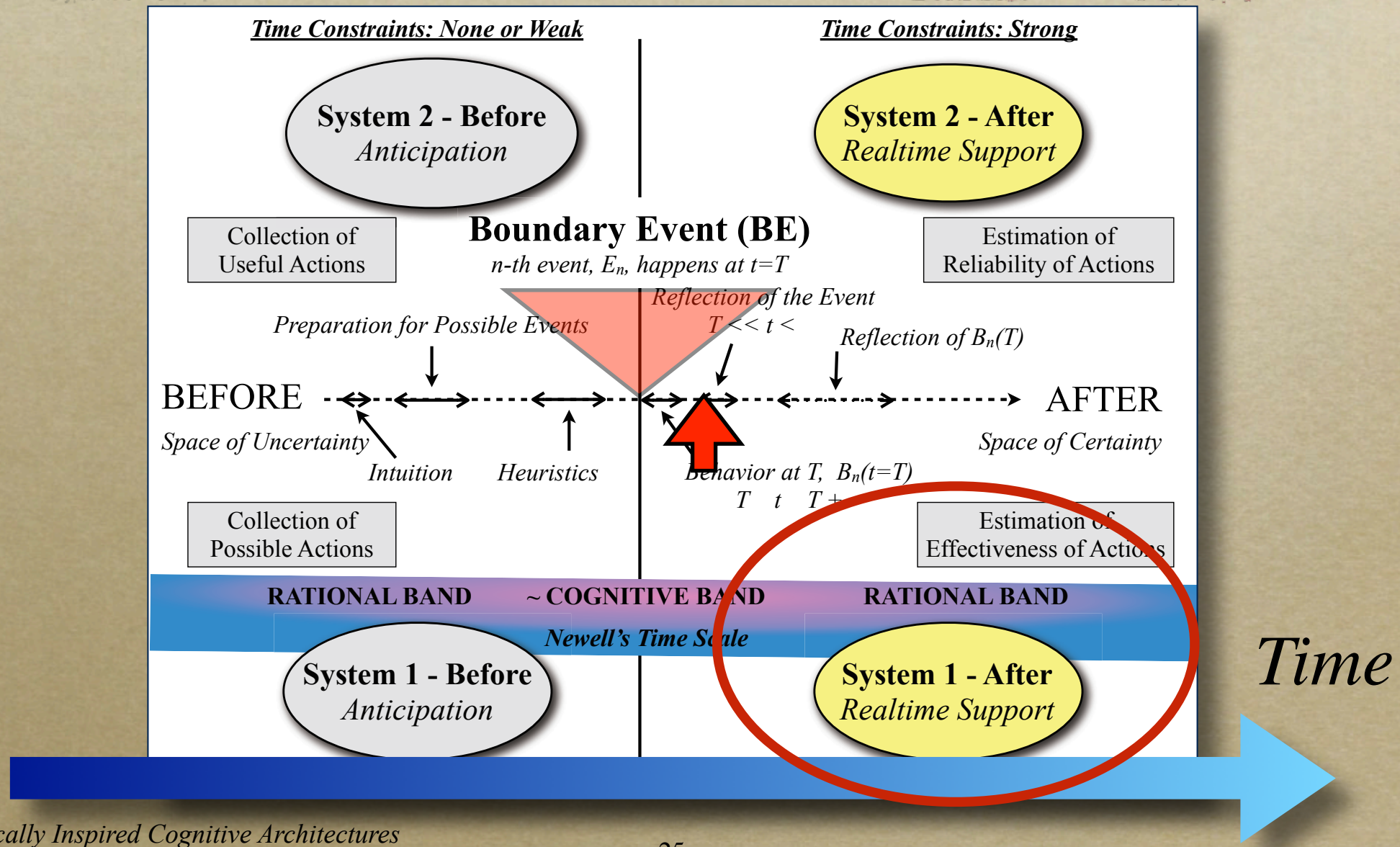

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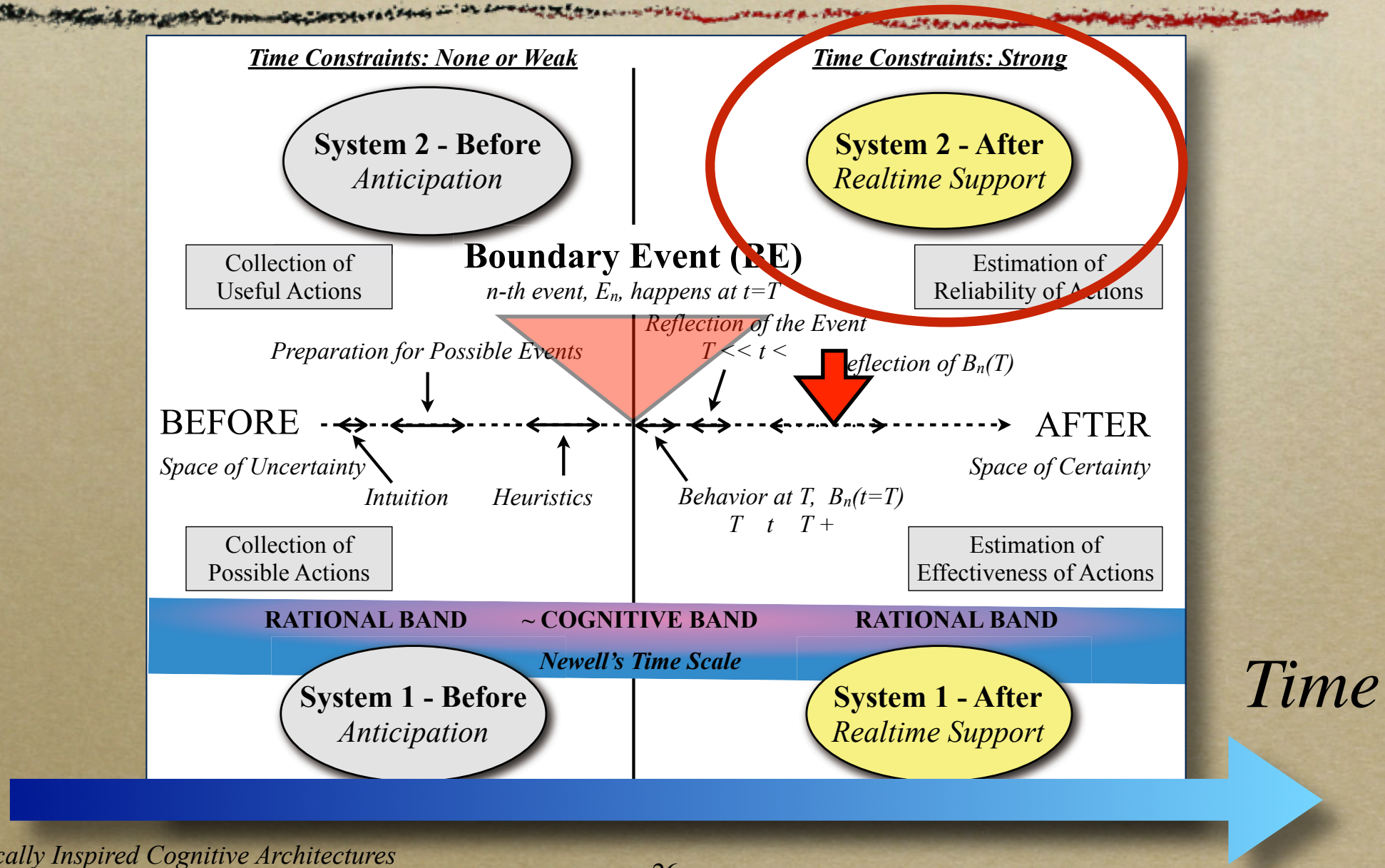

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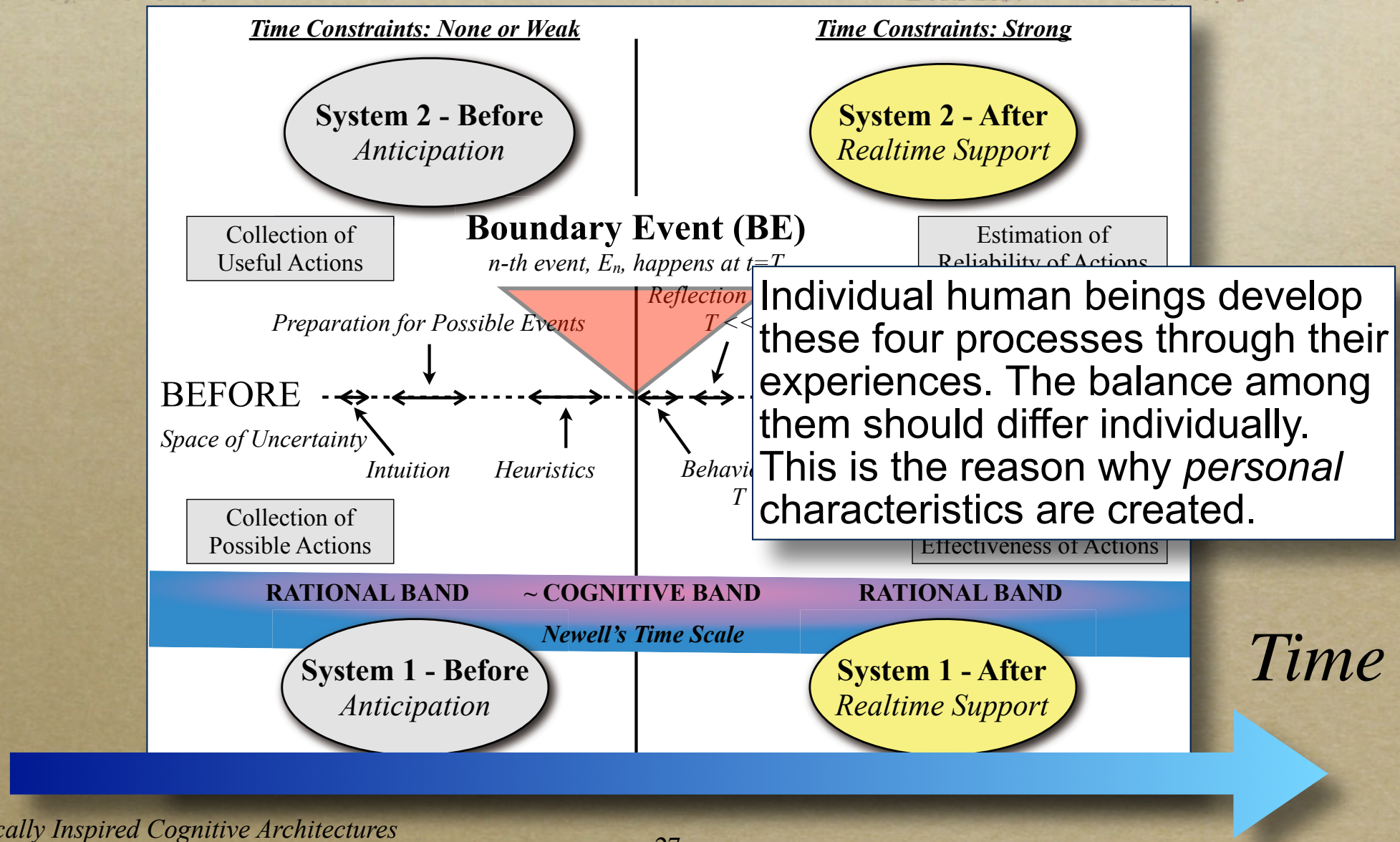


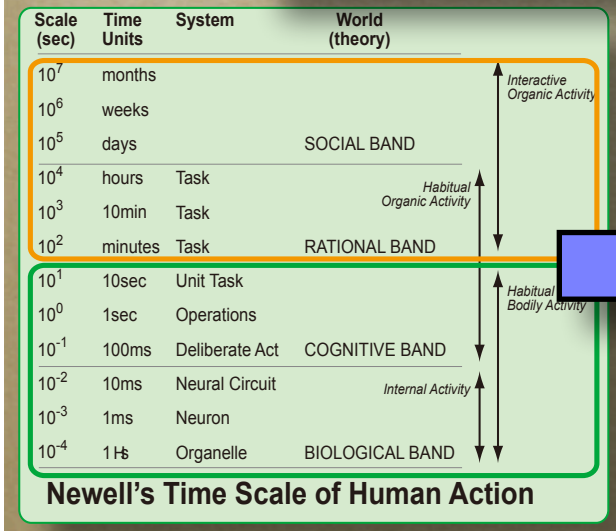
Individual human beings develop these four processes through their experiences. The balance among them should differ individually. This is the reason why *personal* characteristics are created.

Part 2-1: Hierarchical structure of human action selection – An update of Newell's time scale of human action

Abstract: *What we observe as each individual's physical behavior is the results of a multiple processing with a PDP system, not with a single unified system. This PDP system is organized evolutionally, and realized as a neural network system, including the brain, the spinal nerves, and the peripheral nerves. This paper illustrates a matrix representation of the relationships between the hierarchical structure of cognition under Two Minds and the hierarchical structure of the neural network system under PDP.*

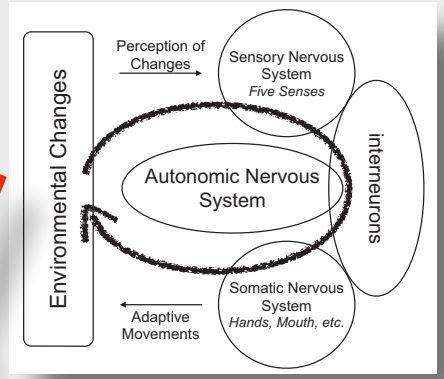
Updating Newell's time scale of human action

Continuous cyclic loop of perception and movement



Four processing modes of MHP/RT

Cyclic processing of MHP/RT



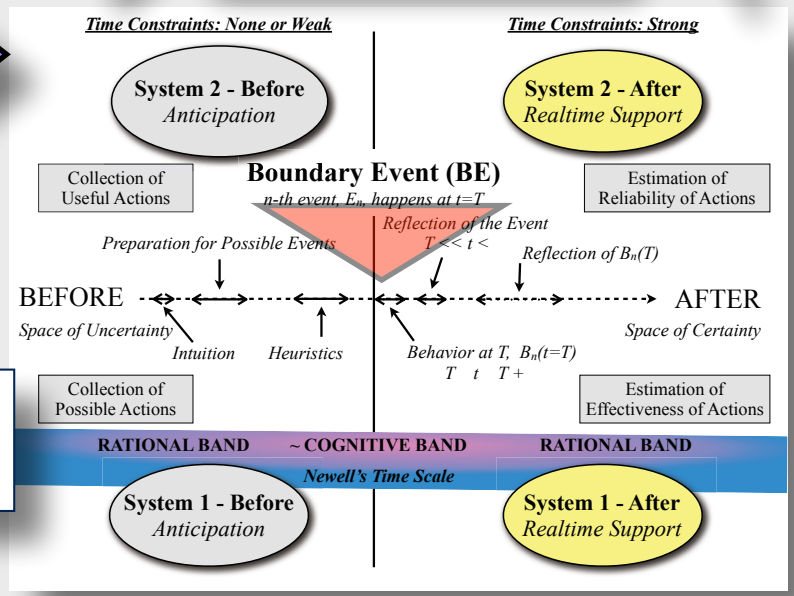


Table 1 of the paper

Table 1: Relationships between the hierarchical structure of cognitive mechanism and that of neural networks.

Hierarchical Structure of Neural Networks	***Hierarchical Structure of Cognitive Mechanism***		
	System 1 of Two Minds		*System 2*
	Level-1	*Level-2*	*Level-3*
	Multi-dimensional perception	*Vision-oriented structural multi-dimensional perception*	*Language, one-dimensional sequence of sound, and non-verbal symbols*
Architecture for Processing	autonomous automatic behavior control	autonomous automatic behavior control + conscious information processing when needed	Conscious information processing; natural formation of grammar; perceptron
Formation Process	genetic	genetic + epigenetic	epigenetic (meme)
Number Sense	multi-valued stimuli	voluntarily formed perceptron using visual patterns; comparative cognition	mathematics; deliberate consideration
Contents	any changes around the self	three-dimensional space recognition, linear continuous change, visual + auditory information	representation of procedural knowledge; continuity under non-linear links; structural decomposition and reconstruction; grammar and notation
Acquisition	experience	imitation of bodily movement	learning of formality + confirmation of the results of experience and procedural understanding; not systematic understanding; uncertain in reproduction
Role of Cognition	for individual; intuitive understanding; used for adaptive reaction	for individual and society; behavior-ecological understanding; used for habitual behavior	for society; conceptual understanding; used for sense making

Three Layers of Interneurons System

- **Two layers in the autonomous automatic behavior control processing, both of which controlled by feedforward loops**
  - *Level-1: Associated with reactive activities carried out by the spinal nerves characterized by automatic and simple reflexive movements*
  - *Level-2: Associated with reactive activities carried out by the bulb or the cerebellum characterized by automatic complex reflexive movements*
- **One layer is associated with the conscious information processing, controlled by feedback loops**
  - *Level-3: Associated with activities carried out by the frontal lobe and the cerebrum characterized by deliberate movements*

Developmental Paths

- **Early stage: 0 ~ 6 years of age**
  - *Feedforward loops are the dominant control mechanism*
  - *0 ~ 3 years of age:*
    - Establishes inter-connections between Layer-1 and Layer-2
  - *4 ~ 6 years of age:*
    - Acquires the skill of behaving in relation with the other persons
- **Middle stage: 7 ~ 12 years of age**
  - *Acquire the skill of logical thinking by means of the first order logic by using letters or symbols and that of cooperation with the other persons*
  - *Key is the existence of symbols that intervene various connections between input and output*

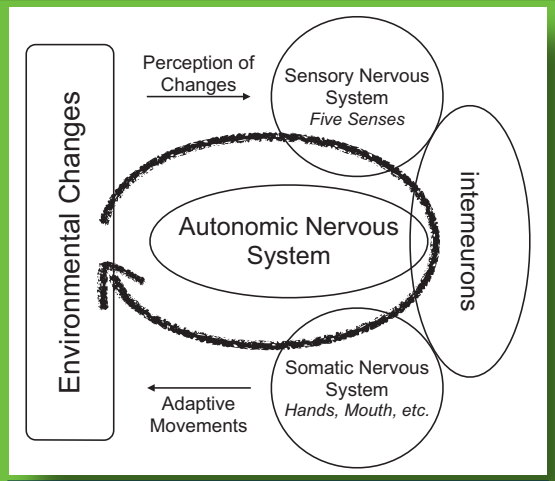
Developmental paths

- **Later stage: 13 ~ 18 years of age**
  - *Feedback loops come into play, which are used to form language processing circuits in a single layer, Layer 3*
  - *Interconnections of the neural networks evolve among the three layers*
    - Ability of logical writing by using an ordinary language affects significantly the evolving process
    - Without language, structural recognition is formed dominantly via visual information
    - When accompanied with language, it makes possible to represent the visual information in a highly logical way, the vision-based structural recognition is significantly augmented to become a structure that can be dealt with a language-based logic system
- **Final stage: 18~ years of age**
  - *Feedback loops become dominant, which make possible to form a compound language processing circuits*

Part 2-2: Topological Considerations of Memory Structure

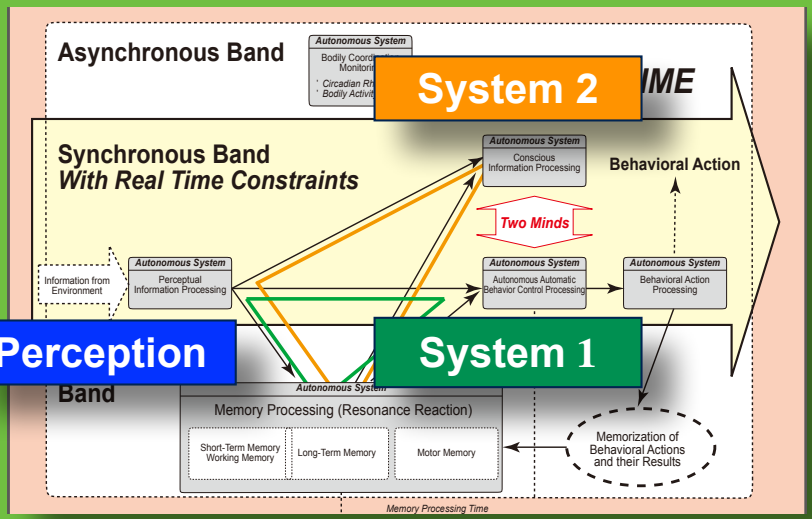
Abstract: *The human memory system is an integration of three distributed memory systems associated with respective autonomous organic systems; the perceptual system that takes care of sensory input from the environment, the conscious system that performs deliberate decision making, and the unconscious system that carries out action selections in the environment. The memory system works as a memory component in the comprehensive brain model, MHP/RT (Kitajima & Toyota, 2013), which is capable of simulating human daily behavior considering the real time constraints that should define strong mutual dependencies among the three systems. This paper reconsiders MHP/RT's memory system by mapping it on the real interconnections between the cranial nerves and the spinal nerves to obtain a topological representation of the distributed memory system.*

Memory Structure: MD Frame



Memory is created via working of autonomous nervous system.

Each autonomous system in MHP/RT has its own memory; each memory system records the traces of its working over time



Organization: MD Frame

Consciousness
RMD-Frame: Open System in Simple Cross Network
> Retrieval of Episodic RMD-Frame via OBJECT
> Construction of Relational RMD-Frame
> Linkage of RMD-Frames to Construct Episode
> OBJECT Creation causes OBJECT Memory

Phoneme Sequence Analysis Creates:
> Language Structure (Grammar)
> OBJECT Relation Matrix
> Web of Categories

System 2

Perception

Add Information via the following Operations
> Change in time (Differentiation)
> Mutual relationship among OBJECTs (Correlation)

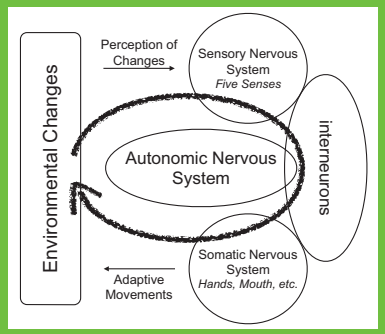
Integration of Memories
> Individual OBJECT Memory
> Integrated OBJECT Memory
> Linkage via Mutual Referencing
> Conscious Behavior by Connecting RMD to BMD
> Prioritization with Reality endorsed by BMD

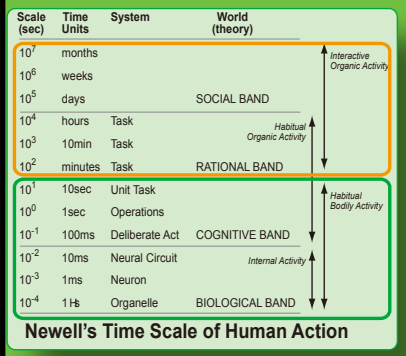
Perception
OBJECT Segmentation causes OBJECT Memory
> OBJECT Decomposition
> OBJECT Categorization

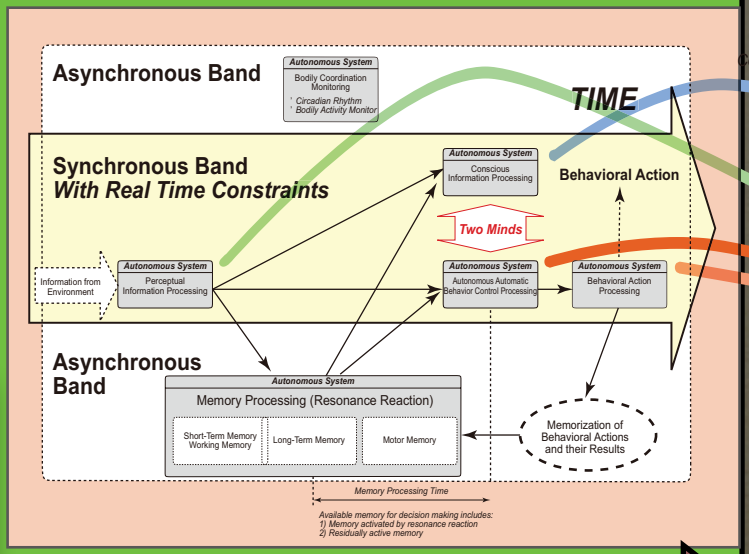
System 1

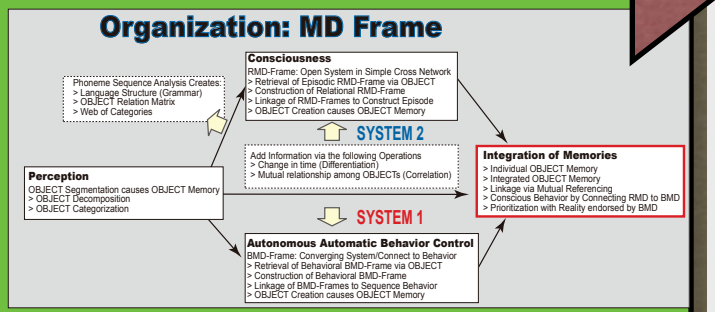
Autonomous Automatic Behavior Control
BMD-Frame: Converging System/Connect to Behavior
> Retrieval of Behavioral BMD-Frame via OBJECT
> Construction of Behavioral BMD-Frame
> Linkage of BMD-Frames to Sequence Behavior
> OBJECT Creation causes OBJECT Memory

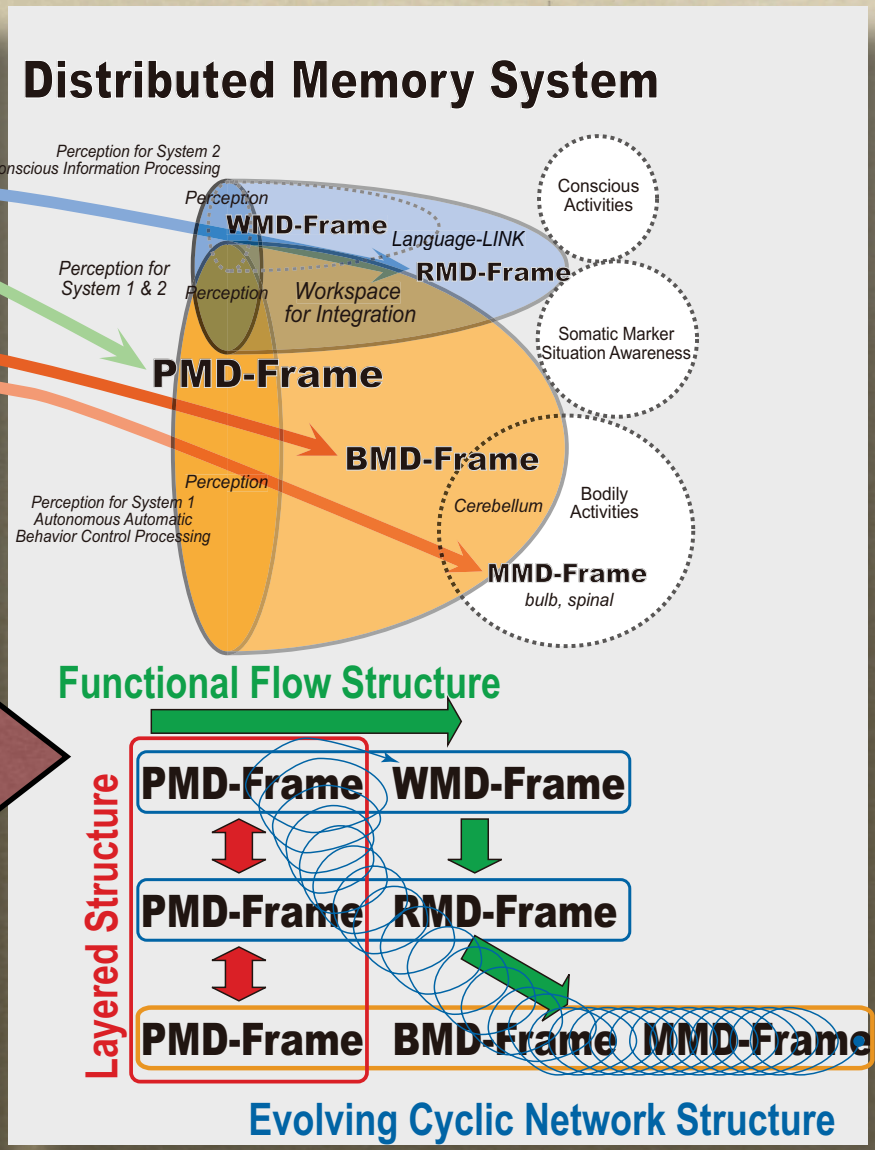
Memory Structure



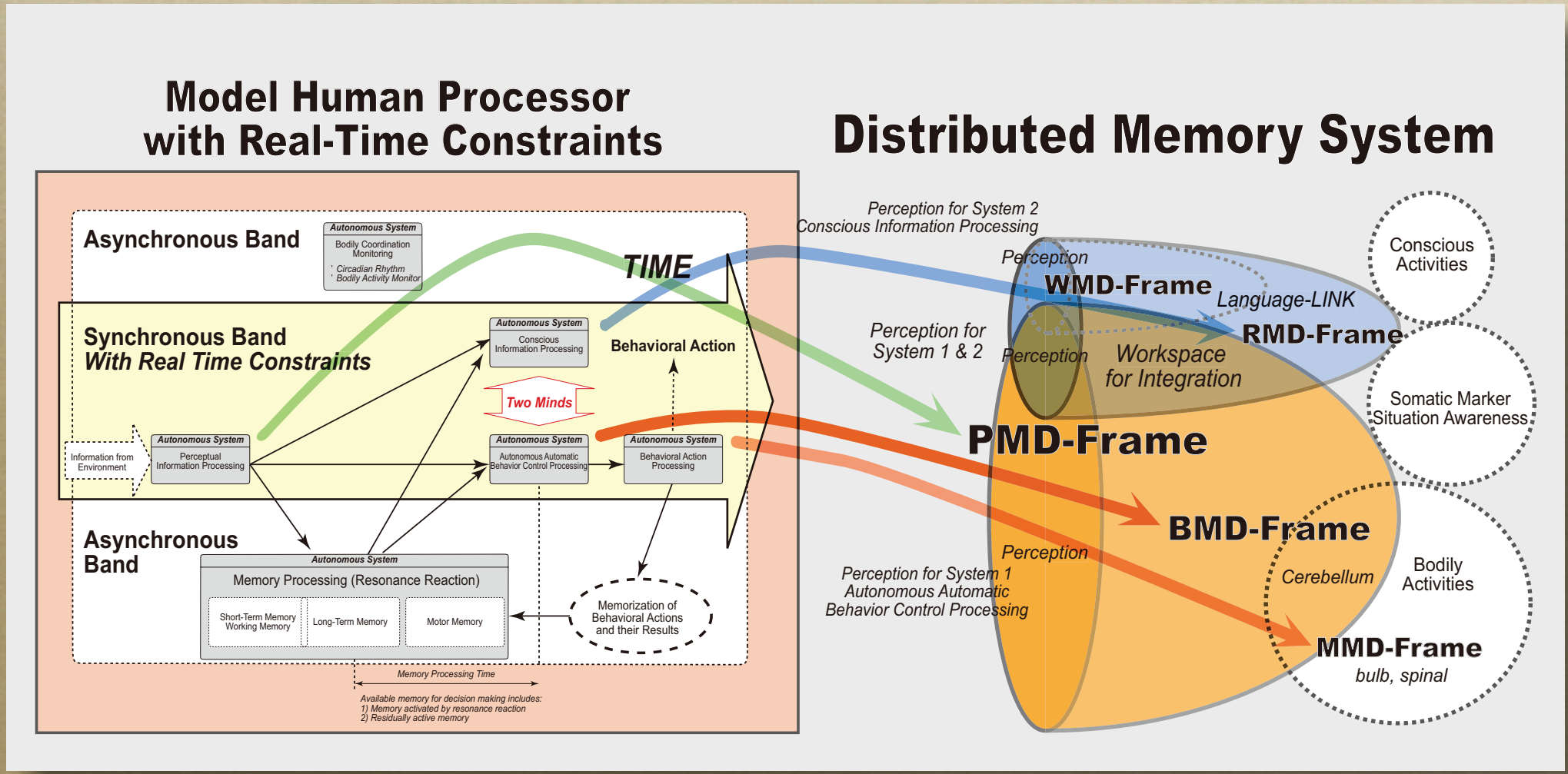








Multidimensional frame as a distributed memory system



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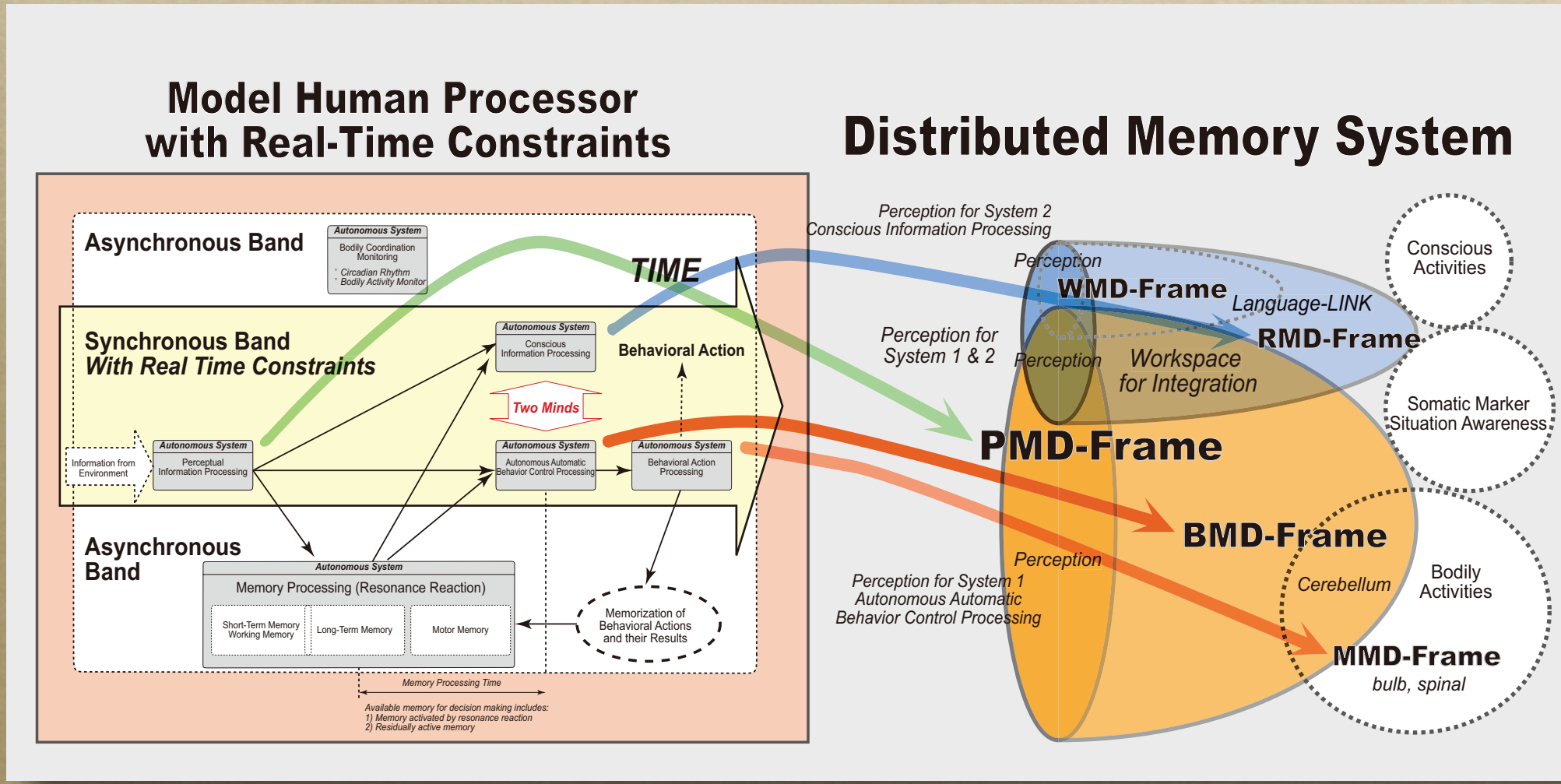
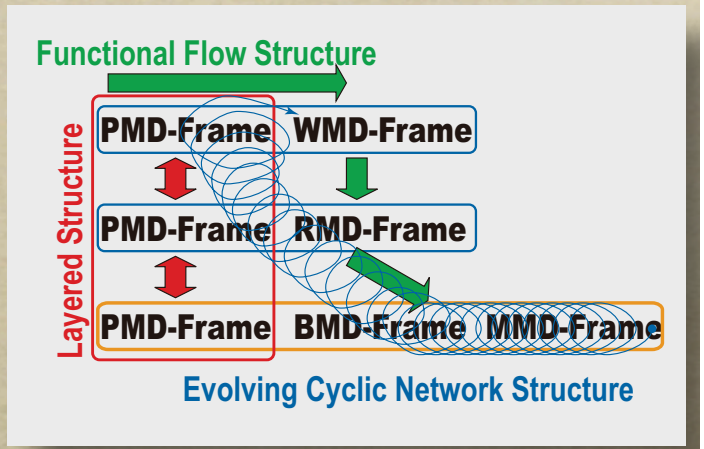


Three Structures in MD-Frames

- **Functional flow structure:**
  - *Describes memory activation paths starting from PMD-frames to WMD-frame, RMD-frame, or BMD-frame to MMD-frame.*
  - *Describes how perception triggers motions.*
  - *MMD-frame is the terminal MD-frame and therefore the paths from WMD-frame to RMD-frame, and RMD-frame to BMD-frame exist.*

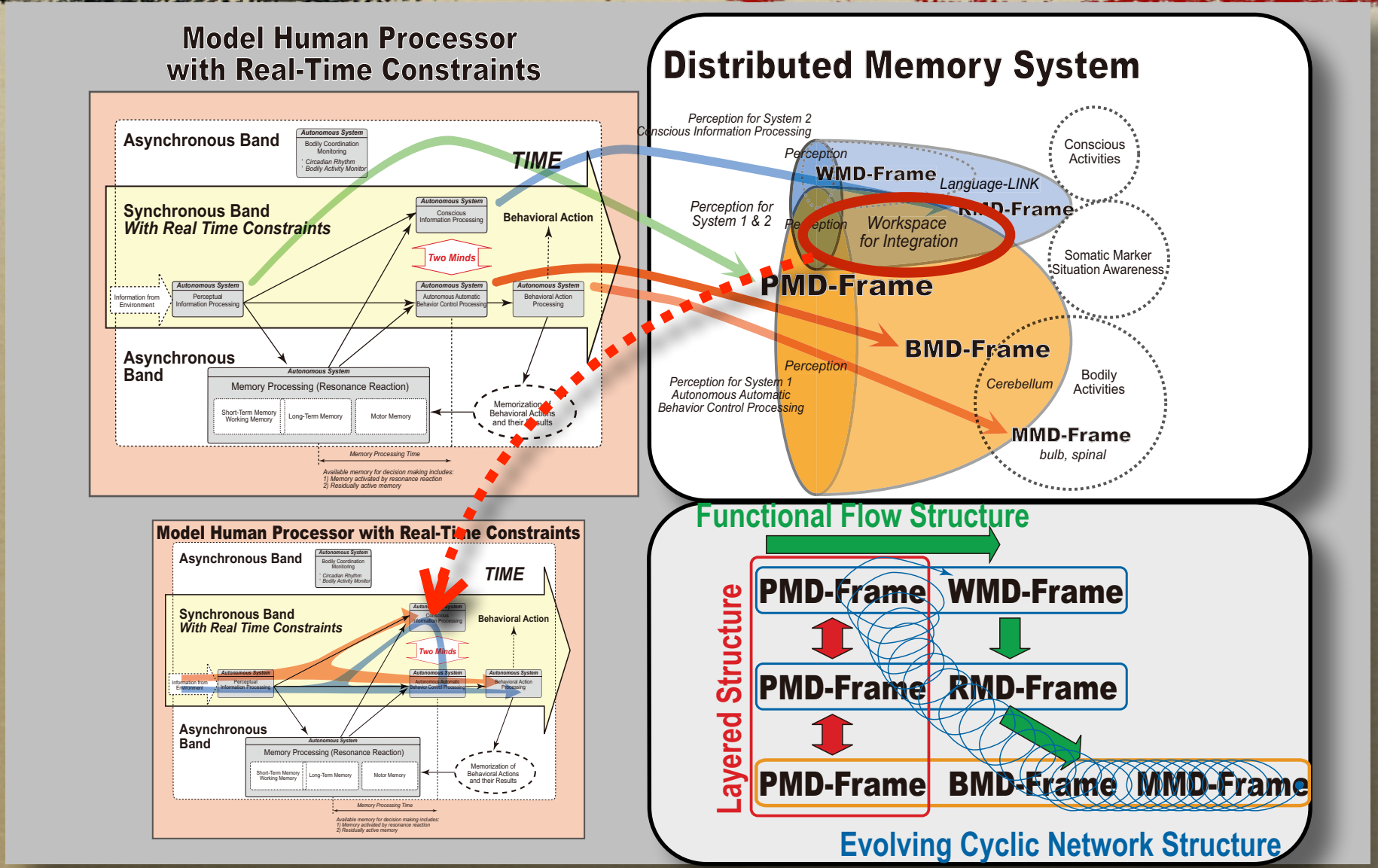


- **Layered Structure**
  - *PMD-frame — WMD-frame layer:*
    - The top layer controlled by words. It consists of simple one-dimensional array of symbols, logically constructed language, grammars that specify language use, etc.
  - *PMD-frame — RMD-frame layer:*
    - The middle layer that resides on the behavioral eco-network for the individual. In this layer, one acquires the meaning of behavior in the social ecology.
  - *PMD-frame — BMD/MMD-frame layer:*
    - The bottom layer that creates a behavioral eco-network for the individual. This is a cyclic network starting from PMD-frame towards MMD-frame, and returning to PMD-frame.
- **Evolving cyclic network structure**
  - *Respective autonomous systems generate distributed memories for their use, and the memories are cyclically related and in effect topological.*

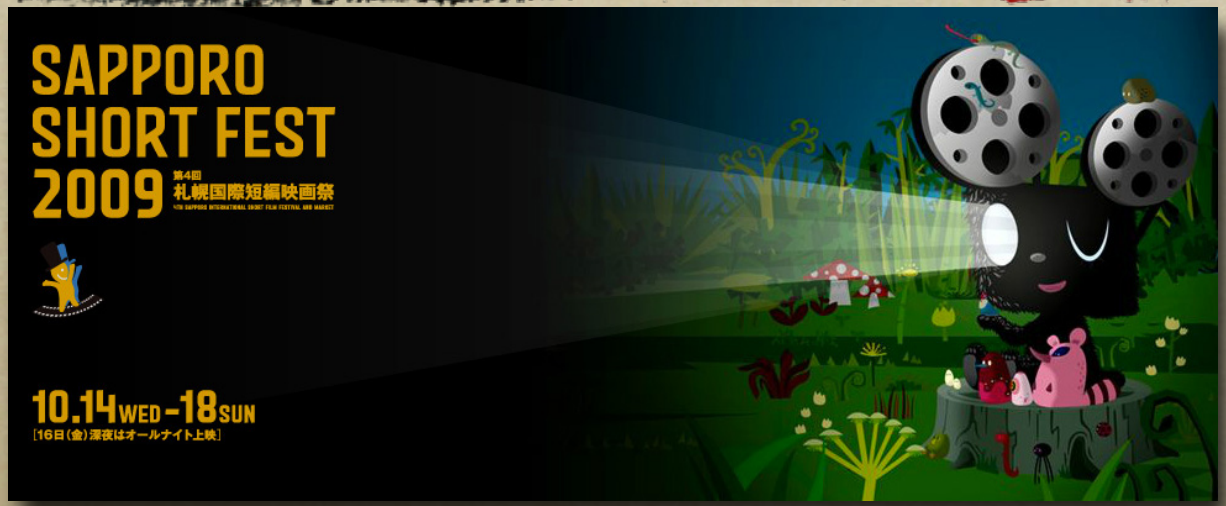
Part 2-3: The role of consciousness in memorization: Asymmetric functioning of consciousness in memory encoding and decoding

Abstract: *… this paper provides a deeper understanding of the role of consciousness in memorization, or memory encoding, based on MHP/RT, with the supporting empirical evidence consistent with the following prediction. MHP/RT assumes that decision-making and action selection should be controlled by Two Minds in general, and Four-Processes in detail. Four-Processes distinguishes the functioning of System 1 and 2 before and after an event. Four-Processes predicts that deliberate reflection of the past event using System 2 would create a memory encoding of the event that would be recallable in the future; on the other hand when the event is processed solely by System 1, it would create a memory encoding that is not consciously recallable via System 2 in the future. This paper provides evidence of the asymmetric functioning of consciousness in memory encoding and decoding that is consistent with this prediction from an experiment at a movie theater where the participants encoded the movies into their memories as they usually would do, and asked to decode them afterwords.*

Distributed Memory System



Observational field study at SSF



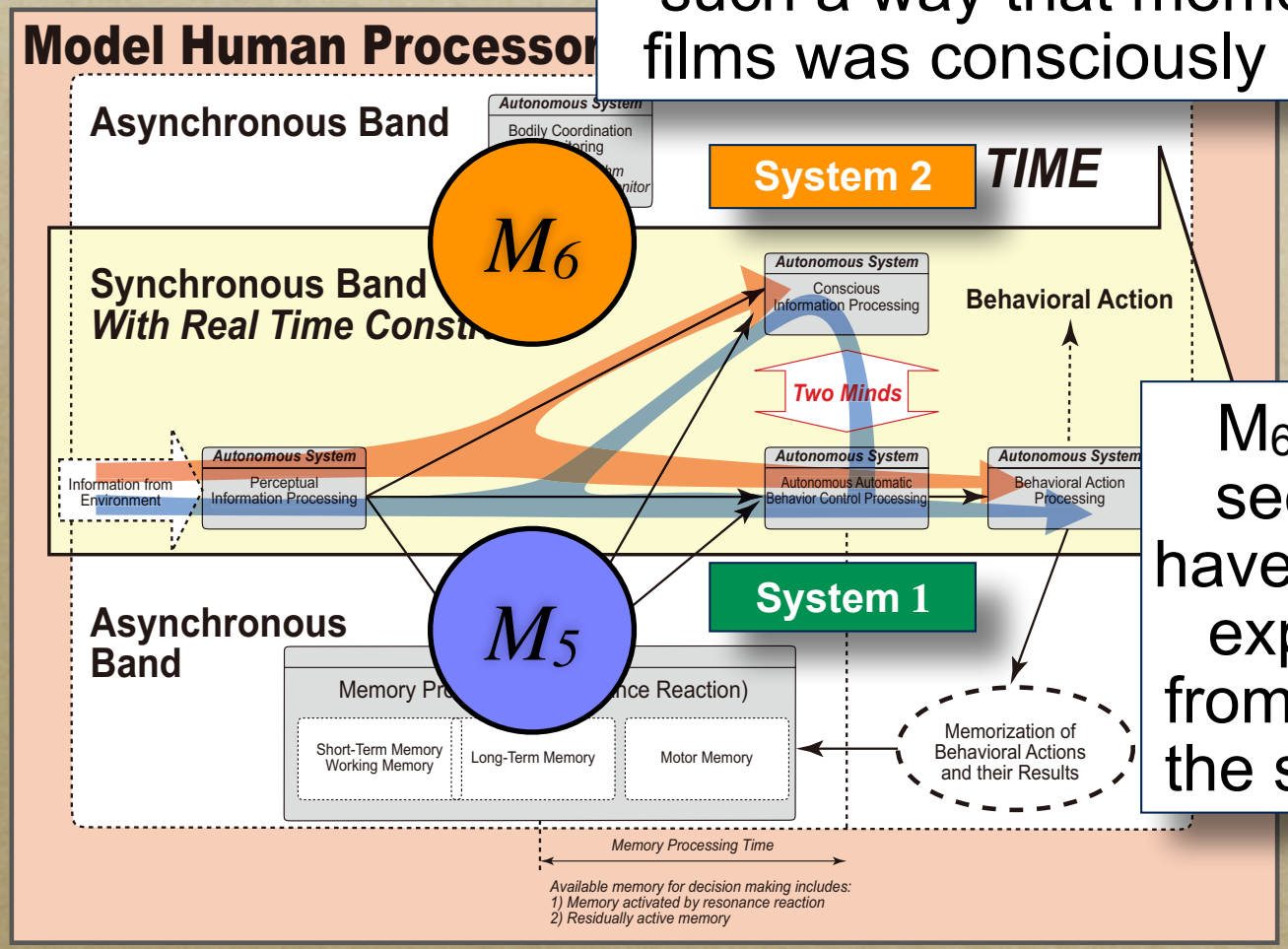
Images of the behavior record used in the retrospective interview.

Results

- **System 1's reaction**
  - *Autonomic nervous system reaction*
    - Some monitors exhibited similar autonomic nervous system reactions to the same program
    - M_5 and M_6 exhibited similar reactions while watching the programs
- **Memory of events**
  - *M_6 barely remembered the contents*
- **They exhibited similar reactions while watching the programs, but they exhibited very different memory in their responses during the retrospective interviews.**

Four-Processes and Memory

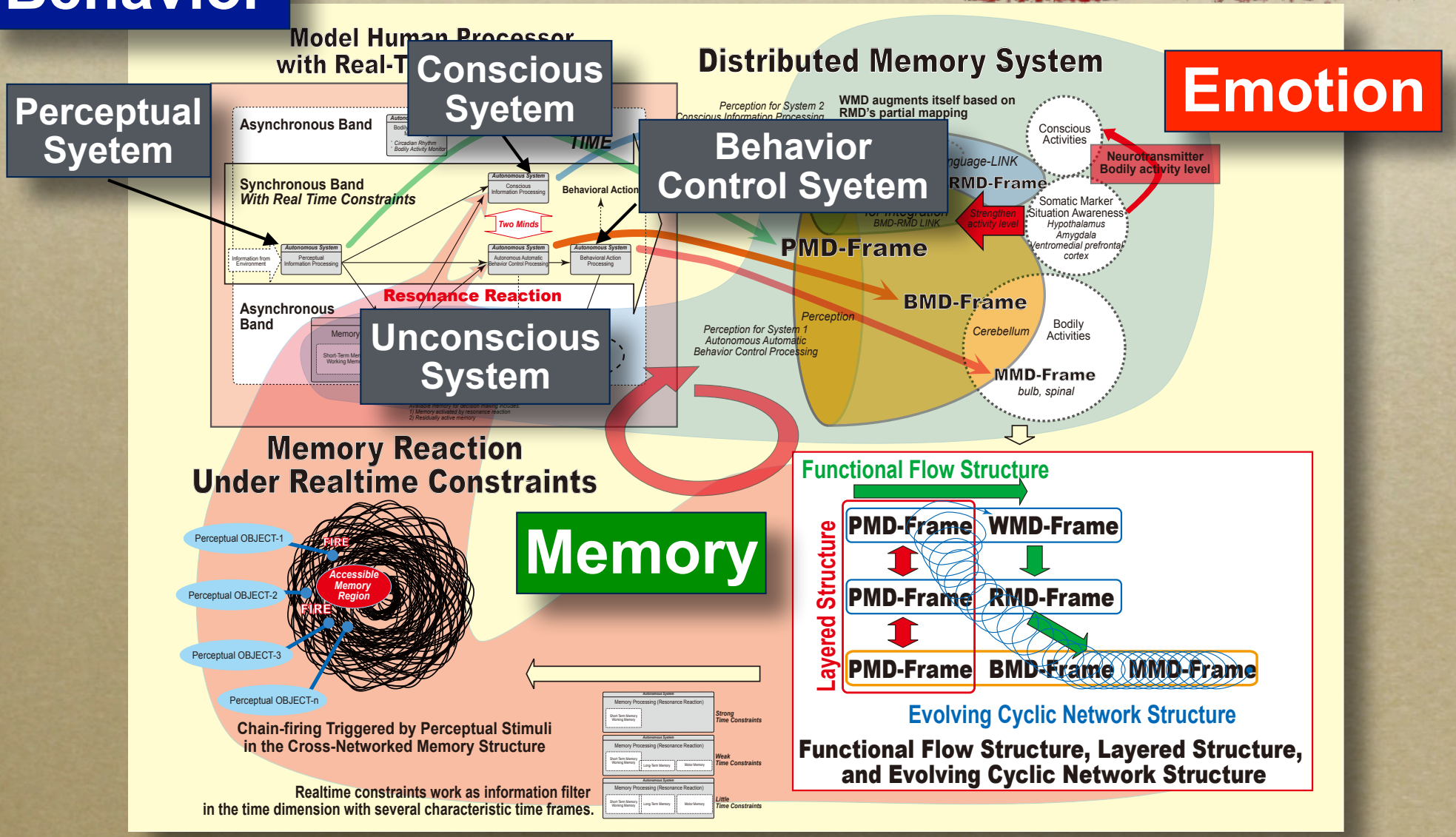
M_6 did not process the films in such a way that memory of the films was consciously recallable



M_6 and M_5 seemed to have the same experience from watching the short films

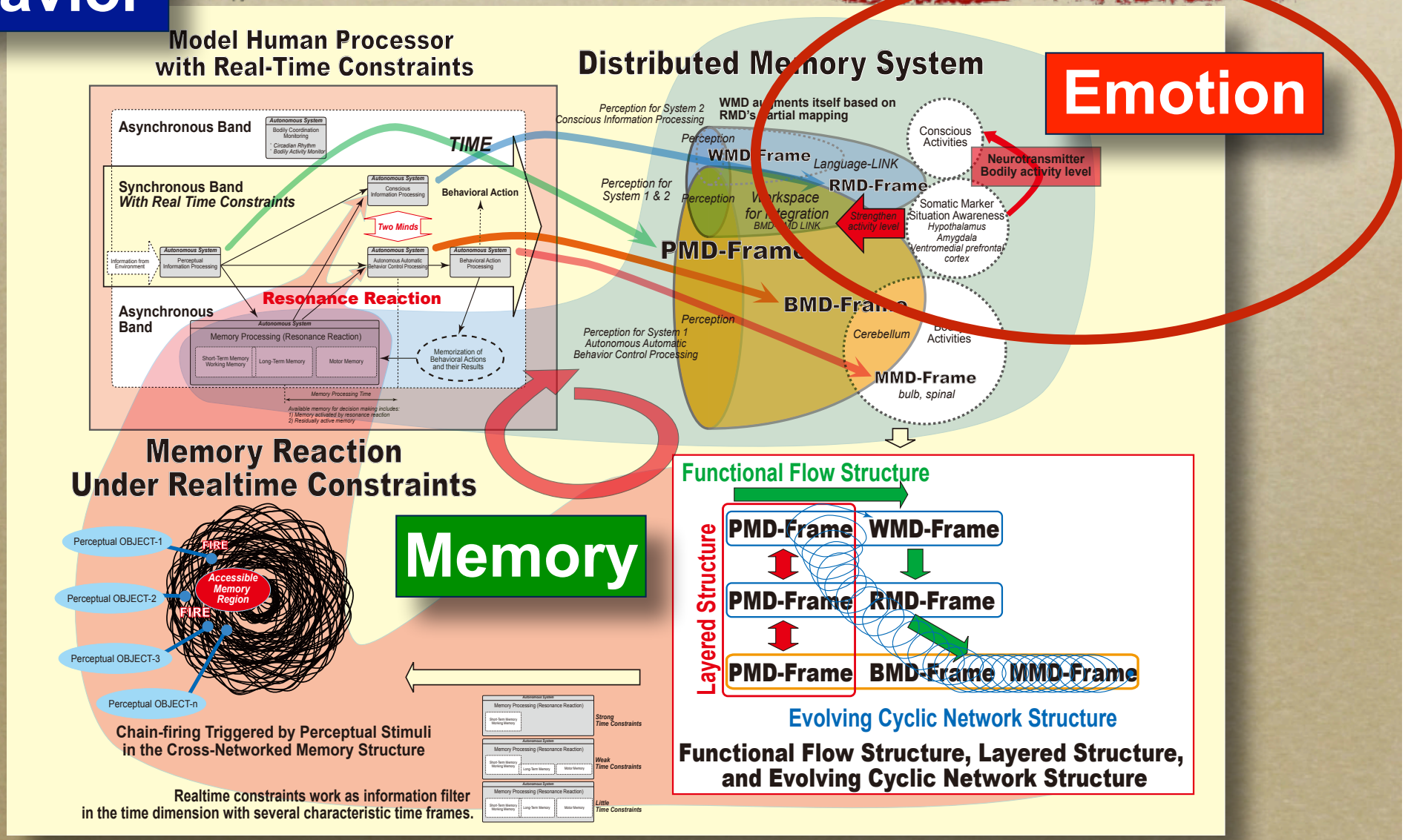
Conclusion: Behavior, Memory, Emotion and Consciousness

Behavior



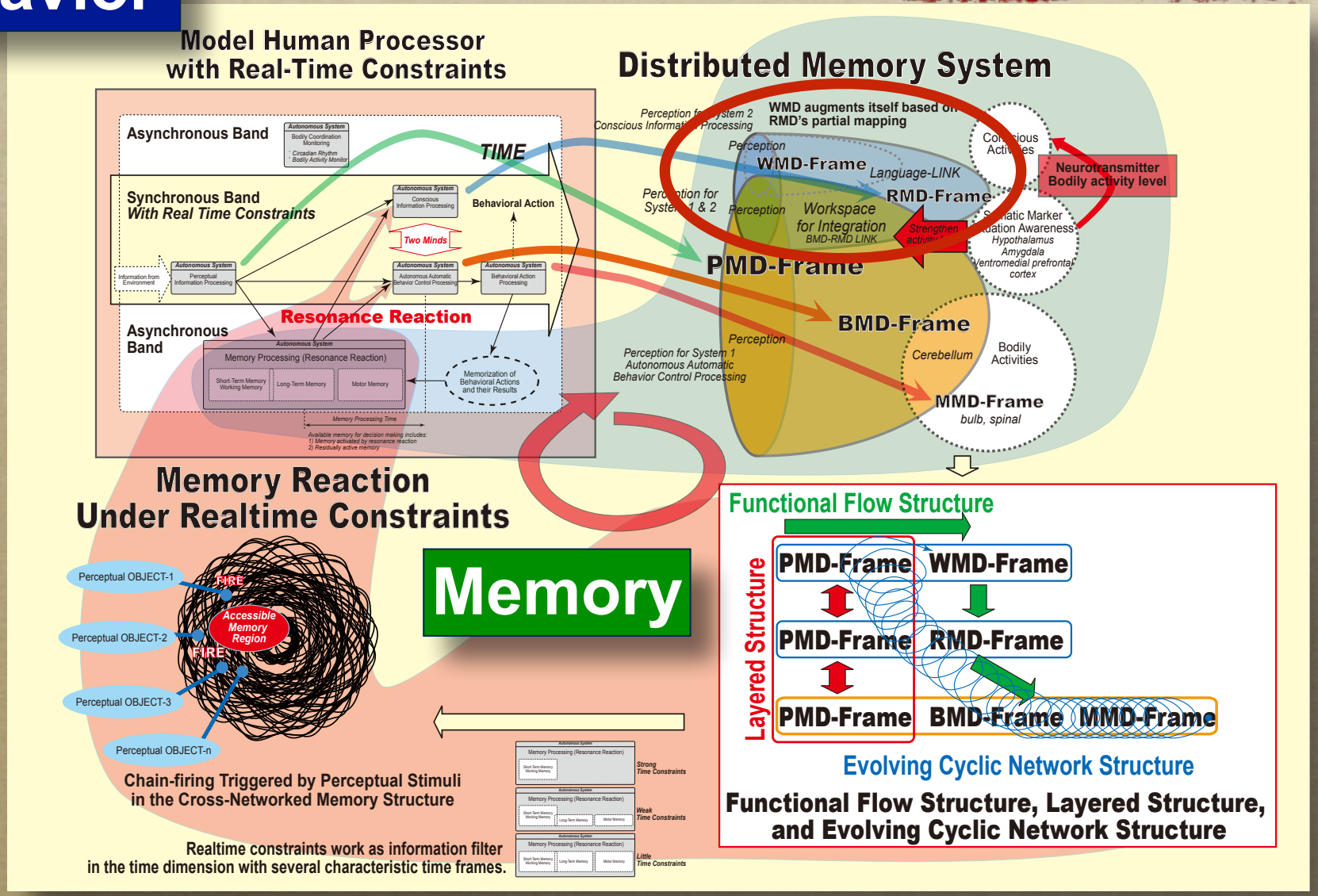
Conclusion: Behavior, Memory, Emotion and Consciousness

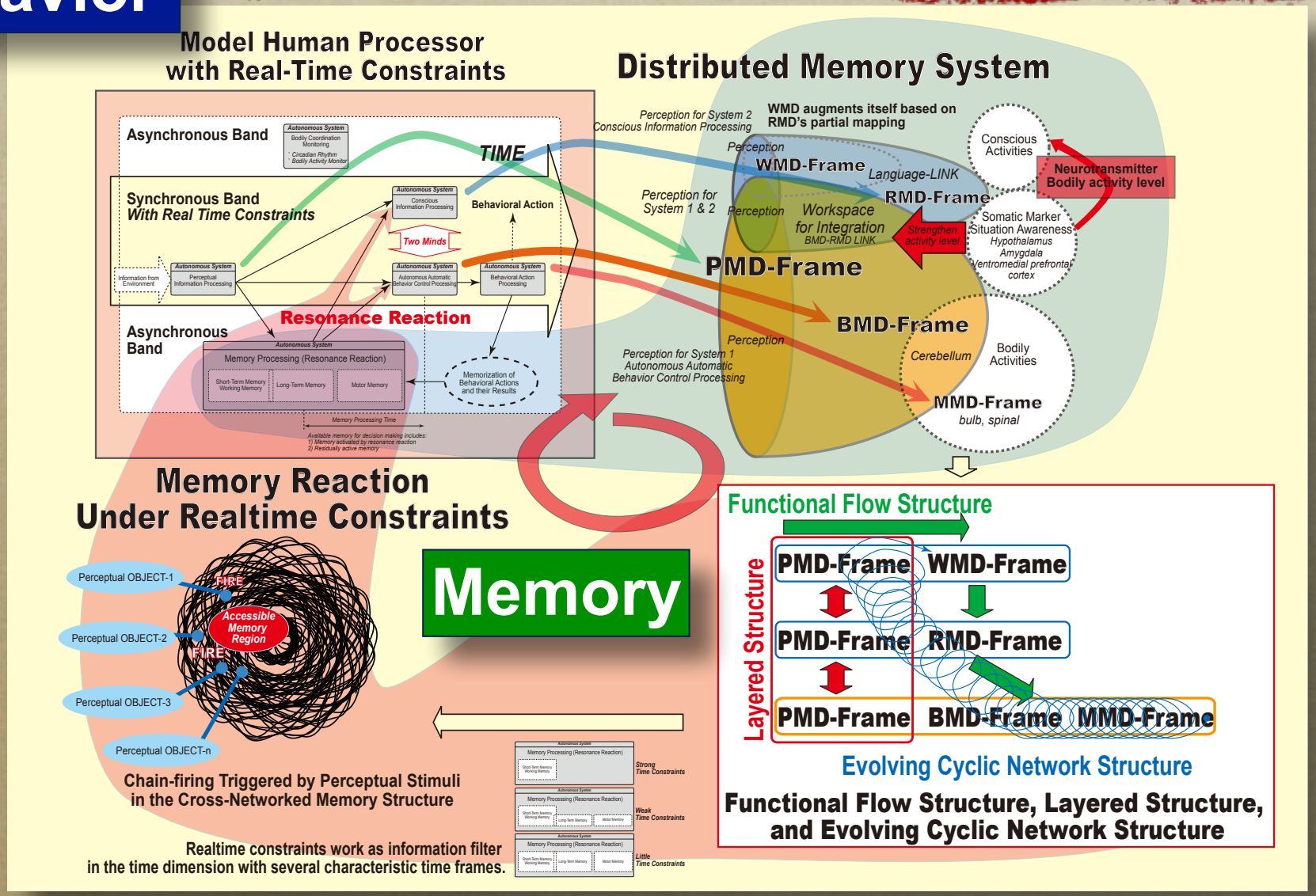
Behavior



Conclusion: Behavior, Memory, Emotion and Consciousness

Behavior



Conclusion: Behavior, Memory, Emotion and Consciousness

Behavior