O-PDP System: Structure and Process

$\sim$ In Quest of a Unified Theory of Mind $\sim$

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1. O-PDP: Organic Parallel Distributed Processing

O-PDP is built on ...

year	name	work
1986	David Rumelhart	Parallel Distributed Processing [1]
2003	Daniel Kahneman	A Perspective on Judgment and Choice [2]
1962	Herbert Simon	The Architecture of Complexity [3]
1990	Allen Newell	Unified Theories of Cognition [4]
2011	Larry W. Swanson	Brain Architecture [5]

[1] David E. Rumelhart, James L. McClelland, and PDP Research Group. *Parallel Distributed Processing: Explorations in the Microstructure of Cognition: Foundations*. A Bradford Book, 7 1987.

[2] Daniel Kahneman. A perspective on judgment and choice. *American Psychologist*, 58(9):697–720, 2003.

[3] Herbert A. Simon. The Architecture of Complexity. *Proceedings of the American Philosophical Society*, 106(6):467–482, 1962.

[4] Allen Newell. *Unified Theories of Cognition (The William James Lectures, 1987)*. Harvard University Press, Cambridge, MA, 1990.

[5] Larry W. Swanson. *Brain Architecture*. Oxford University Press, 2011.

Life is formed as an Organic-PDP (O-PDP) system

- Life is formed as an O-PDP system, self-organized under the whole collection of O-PDP systems.
- The entire O-PDP systems exist quasi-stably in an organic self-consistent field – an individual exists surrounded by the other individuals with symmetric relationships.
- Each O-PDP acts circularly as a whirlpool in the surrounding environment characterized as dissipating structure[†)].

†) A dissipative system is a thermodynamically open system which is operating out of, and often far from, thermodynamic equilibrium in an environment with which it exchanges energy and matter. A dissipative structure is characterized by the spontaneous appearance of symmetry breaking (anisotropy) and the formation of complex, sometimes chaotic, structures where interacting particles exhibit long range correlations. Examples in everyday life include convection, turbulent flow, cyclones, hurricanes and living organisms.

Activities of an O-PDP system guided by GOMS

- The dynamic relational structure behind the activities of an O-PDP system is represented as GOMS – Goals, Operators, Methods, and Selection Rules.
- GOMS is not a point to define O-PDP system's activities but serves as a pseudo-point that guides their activities.
- Trajectory of the actual activities of an O-PDP system passes through the neighborhoods of the points representing GOMS.
- The goal defined by an O-PDP system under the constraints of bounded rationality is different from the ideal goal, G, to achieve, i.e., accomplishing its expected role in Gaia.
- O-PDP systems as a whole form a balanced circular network of their entire activities in the ecosystem of the earth, Gaia, as a Parallel-GOMS (P-GOMS) system.

Understanding O-PDP systems from inside (c.f., Simon [6])

- Observing from outside, O-PDP systems show apparently continuous trajectories, inherently indiscernible and no clue for inferring their structures.
- O-PDP systems cannot be understood from outside but from inside: Needs to elucidate their constituents and relationships.

- "Understanding from inside" is to understand the following:
  - Energy flow within the network of O-PDP systems as a whole,
  - Exchange of energy within individual energy bands,
  - Circulation of energy in the entire network, and
  - Activation paths of the elements of an O-PDP system that take part in the energy exchange

[6] Herbert A. Simon. *The Sciences of the Artificial*. The MIT Press, Cambridge, MA, third edition, 1996.

Formation of an O-PDP system through "continuous relativization of time" – *absolute time does not exist*

- An O-PDP system is formed under the stable circulation of the global environment, e.g., the rhythm of the days, the seasons, etc.
- Although time flows irreversibly, the stable circulation makes the temporal relationships between cyclic O-PDP processes relative; time is not absolute but relative.
- Trajectories of an O-PDP activities are not fixed but fluctuate because the environment is a complex system, resulting in emergence of a band structure in the O-PDP trajectory space where repeated trajectories constitute a band (cf. Simon [3]).
- Continuous relativization of time makes possible to make crude predictions of the behavior of the O-PDP system.

Evolution of an O-PDP system

An O-PDP system is a collection of autonomous systems, evolved through adaptation to the environment.

- An O-PDP system consists of a collection of distributed processes that work in parallel autonomously (cf. Kahneman [2] and Newell [4]).
- Each autonomous process needs to adapt to the unpredictable environment, resulting in fluctuations of its performance.
- The fluctuating O-PDP system has a chance to form a self-organized structure that adapts best to the environment.
- The adaptive superiority of the O-PDP system gives it the potential to make distinctive development or evolution.

Trace of evolution and cognitive system architectures‡)

- An O-PDP system is among the system architectures capable of reproducing characteristics of current human beings, and
- The one that intersects with the trace of evolution.

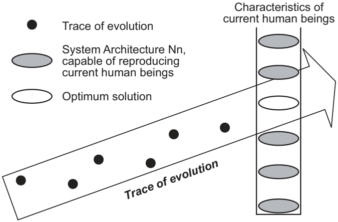

Figure 1: O-PDP is the system architecture on the trace of evolution.

‡) A cognitive architecture can refer to a theory about the structure of the human mind. One of the main goals of a cognitive architecture is to summarize the various results of cognitive psychology in a comprehensive computer model. However, the results need to be formalized so far as they can be the basis of a computer program. The formalized models can be used to further refine a comprehensive theory of cognition, and more immediately, as a commercially usable model.

2. Forming an O-PDP system

Consider "How life emerges and exists" starting from · · ·

- Life emerges in a preexisting structure, which is the global environment surrounding the life to emerge.
  - *this section*
- Life exists as a system that operates under the mechanism of parallel distributed processing.
  - *the sections to follow*

Preexisting structure: Global environment

Life has evolved through adaptation to the global environments:

- **Atmosphere:** the earth's atmosphere fluctuates at the meteorological scales showing chaotic behavior.
- **Sea:** there are tidal currents and the surface layer affected by the atmosphere showing chaotic behavior.
- **Periodic circular structures:** stable periods of rotation and revolution around the sun with a close-circular orbit as a planet of the solar system.
- **Gravity:** upper vs. lower directions, defined by the earth's gravity.
- **Energy:** future vs. past directions, defined by the direction of energy flow as the dissipative structure of the earth.

Life is formed under preexisting structures:

Structural pressure determines the direction of life evolution:

- Under the dissipative structural space, the earth, the fundamental structural pressure is prerequisite to the life, born and active in it, and prescribes the direction of life evolution.
- Life is formed as an adaptive body with the functional and structural features of GOMS.

Perception and motion: $M \otimes N$ mapping

Preexisting conditions:

- In the global environment before life occurs, there existed multiple-layered structure equipped with means of communicating information in a multi-dimensional space, including light, sound, heat, ion, etc.

Life activities:

- Life interacts with the multi-dimensional environment by using perception and motion as interfaces to it.
- Let the size of dimension of perception and that of motor be M and N, respectively, the function of interface is represented as a mapping in the $M \otimes N$ space.
- Specific numbers of M and N reflect the preexisting conditions of the environment.

Perception and motion: $M \otimes N$ mapping

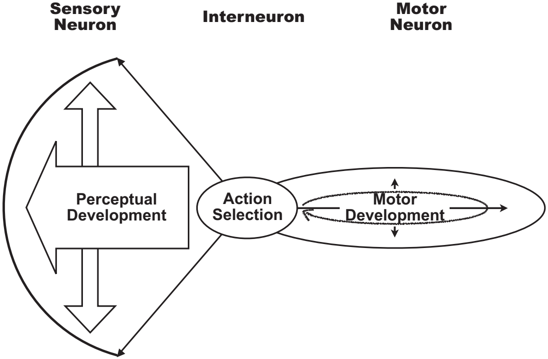

Figure 2: Life activities that map M-dimensional perceptual input to N-dimensional motor output, i.e., $M \otimes N$ mapping by the system of interneurons. Trajectories of the life activities fluctuate, which provides opportunities to the O-PDP system to develop by adaptation.

3. Time scale of human action and development

Band structure

Table 1: Newell's time scale of human action (adapted from [7]), left portion of the table, added with associated acitivities.

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

[7] Allen Newell. *Unified Theories of Cognition (The William James Lectures, 1987)*. Harvard University Press, Cambridge, MA, 1990. page 122, Fig. 3-3.

Nature of a band

- Human actions are hierarchically organized in four bands; BIOLOGICAL, COGNITIVE, RATIONAL, and SOCIAL.
- In-band closed processes are executed in feedforward.
- Processes carried out in upper bands provide feedback to the lower band processes.

Band structure and memory formation

- Activities at an upper band emerge, each of which is associated with a part of the entire sequence of activities, a sub-sequence, performed at a lower band.
- The lower-band action sequence is segmented into sub-sequences, each of which corresponds to one of upper band activities, and due to the fluctuations in processing times of the upper-band activities, relativization of processing times and functionalization of sub-sequences should occur.
- The processing that consists of an upper-band activity associated with a sequence of $M \otimes N$ mappings at a lower band forms a hard circuit peculiar to this processing, which is the process of memory formation.
- The cyclic nature of ecology makes memory cyclic or recursive, which makes a human possible to think the ecology of self.

Interneurons to memorize effective $M \otimes N$ mappings

The genealogy of DNA of vertebrates suggests Perception, Interneuron, and Motion as the basis for development:

- PIM is a basis of formation of body based on neural circuits.
- The whole is formed as PIM develops.

Perception, Interneuron, and Motion:

- P: Perception captures various kinds of environmental changes by sensors with different properties (M-dimension).
- M: Motor movement (motion) is carried out continuously and cyclically from one's birth with gradual development in terms of its accuracy and strength (N-dimension).
- I: Interneurons memorize effective interlocked relationships between P and M in the external environment, to form neural circuits naturally in the form of feed forward and more complex feedback to increase the effectiveness of reactions.

Development by expanding behavioral-ecological bandwidth

- Behavioral ecological categories of vertebrates such as gaining food, raising children, and so on, are almost identical and within a limited range (Figure 9 on page 51).
- Human everyday life is performed cyclically in a behavioral ecological band, which is expanded by acquiring new actions to realize something in the limited behavioral ecological categories and adding them to the existing band.

Development by expanding behavioral-ecological bandwidth

- Actions are realized as an *ad hoc* adaptive combination of various elements of the O-PDP system each time.
- The relationships between elements of the O-PDP system are determined limitedly under the conditions defined by the environment which is not completely predictable but somewhat reproducible and stable at that time.
- Quasi-stable relationships between elements are generated by local relativization of the time relationship between the participating elements and added to the band.

Development by expanding behavioral-ecological bandwidth

- Since each process of performing actions is autonomous, there are chances where multiple processes are initiated in a certain environment, resulting in coincidental parallel activities.
- Even if the timing of execution of two or more parallel processes changes, it can happen all processes are completed within a certain time range with or without any relationships in the respective results.
- If the overall consequences bring good results anyhow, behavior selection in the future might be changed by this memory accociated with rewards.
- Arbitrarily activated processes through conscious thinking can become a part of those expanded memories, making easy for expansion of the memory.

Behavioral-ecological cyclic networks

Table 2: Four behavioral-ecological cyclic networks corresponding to the bands defined by Newell's time scale of human action shown by Table 1.

Name of the network	Activity level	Two Minds
Society level BECN	Organic Interactive	SYSTEM 2
Individual level BECN	Organic Habitual	SYSTEM 2
Body level BECN	Bodily Habitual	SYSTEM 1-2
Motion level BECN	Internal	SYSTEM 1-1

4. Chaining and synchronization

Understanding O-PDP system's performance in terms of chaining and synchronization in topological relationships

- All the elements in an O-PDP system perform actions cyclically, i.e., there is no definite input-output relationships, therefore "topology" of the elements matters.
  - Memory stores the values of the transition points of processing within the same band layer (corresponding to the perceived sensitivity band) which have no absolute time and position. The interconnection of memories – topology – does matter.

- Working of an O-PDP system is best described by:
  · "chaining of its elements" and
  · "synchronization timing of the connected elements"

  in the cyclic process.

Generating and extending time-series memories

- In a complicated integrated relationship in an O-PDP system, a time-series relationship is formed between individual relations.
- Once a relationship is stabilized, it becomes a memory for the participating relations, i.e., a time-series memory.
- Once a time-series memory is formed, individual relations that occur along the time dimension are mutually referenced via the memory of their relationship, resulting in relativization of the relations, i.e., the absolute time disappears at this moment.
- Perceptual stimuli concerning an "event" at T is associated with those at $(T - \alpha', \cdots, T)$ to form a time-series perceptual memory, which could integrate the perceptual results of motor movement at $T + \alpha$ for these input stimuli as well.
- The time range $(-\alpha', \alpha)$ extends as time goes by.

Parallelism in O-PDP and development

- Parallelism in O-PDP includes:
  - Between-bands parallelization due to the differences in the active space-time ranges.
  - In-band parallel executions of multiple functional threads.
- Body plan limits combinations of parallel processes to those effective for developing O-PDP.
  - Body plan is a structural connection relationship between processing elements in terms of how to establish chaining and how to sequence synchronizations.
- Forms of between-bands connections are limited due to the discrepancies in characteristic time-space ranges (Table 1 and 2).

Four forms of memory structure concerning an event

- After the event:
  - When a connection is established between processes in autonomous systems concerning a perceptual event, the autonomous system that establishes a connection to the results of activities in the past locates always "after" the event.
- Before the event:
  - When established connections in some autonomous systems are used for the perceptual stimuli to happen and to the to-be-initiated activities in some autonomous systems, the former locates always "before" the event.
- An O-PDP system inevitably forms four forms of memory structure concerning an event:
  - in-band before/after connections concerning a perceptual event.
  - lower-band – upper-band before/after connections concerning a perceptual event.

Utilizing memory in Two Minds

Feedforward processes before an event (SYSTEM 1-B):

- *Experiential Processing System (SYSTEM 1)* is a fast feedforward control process driven by the cerebellum and oriented toward immediate action.
  - Carried out as Internal and Bodily Habitual Activities at BIOLOGICAL and BIOLOGICAL & COGNITIVE BAND, respectively (Table 1).

Feedback processes before an event (SYSTEM 2-B):

- *Rational Processing System (SYSTEM 2)* is a slow feedback control process driven by the cerebrum and oriented toward future action.
  - Carried out as Organic Habitual and Organic Interactive Activities at COGNITIVE & RATIONAL and RATIONAL & SOCIAL BAND, respectively (Table 1).

Four processing modes in daily activities

- SYSTEM 2 Before Mode: Conscious use of memory before the event, i.e., SYSTEM 2's operation for anticipating the future event, or decision-making.
- SYSTEM 1 Before Mode: Unconscious use of memory before the event, i.e., SYSTEM 1's operation for automatic preparation for the future event, or action selection.
- SYSTEM 1 After Mode: Unconscious update of memory after the event, i.e., SYSTEM 1's operation for automatic tuning of memory related with the past event.
- SYSTEM 2 After Mode: Conscious update of memory after the event, i.e., SYSTEM 2's operation for reflecting on the past event.

5. Action selection in O-PDP

Nature of human behavior selection

Human behavior selection is $\cdots$

- an act as physical behavior,
- a real act as actual energy circulation, and mere inference at SYSTEM 2 does not guarantee realization, so it is only one of the preparatory behaviors for behavior selection,
- a three-tier structure (SYSTEM 1, 2 and language), but SYSTEM 1 plays the main role for continuing chaining processes, and
- uncertain due to the time constraints in the external environments.

Dealing with uncertainty in the environment

- Parallel processes in an O-PDP system deal with the uncertain situations adaptively.
- Advantage of some processes under certain situations results in selection of these processes, bringing in distinctive results.

Four operation modes of O-PDP for behavior selection

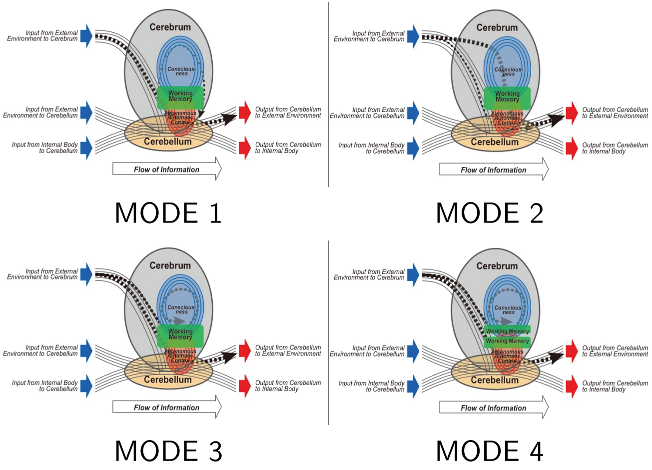

Figure 3: Information flow in four operation modes.

Four operation modes of O-PDP (MODE 1 and 2)

BASIC MODE	
- MODE 1:	Unconscious mechanism driven mode: Synchronous
	A single set of perceptual stimuli initiates feedforward processes at BIOLOGICAL and COGNITIVE bands to take action with occasional feedback from an upper band, i.e., COGNITIVE, RATIONAL or SOCIAL.
DERIVED MODES	
- MODE 2:	Conscious mechanism driven mode: Synchronous
	A single set of perceptual stimuli initiates a feedback process at COGNITIVE band, and upon completion of conscious action selection unconscious automatic feedforward processes is activated at BIOLOGICAL and COGNITIVE bands for taking action.

Four operation modes of O-PDP (MODE 3 and 4)

- MODE 3:	In-phase autonomous activity mode: Asynchronous *A single set of perceptual stimuli initiates feedforward processes at BIOLOGICAL and COGNITIVE bands with one and another intertwined occasional feedback processes from an upper band i.e., COGNITIVE, RATIONAL or SOCIAL.*
- MODE 4:	Heterophasic autonomous activity mode: Asynchronous *Multiple threads of perceptual stimuli initiate respective feedforward processes at BIOLOGICAL and COGNITIVE bands, some with no feedback but others with feedback from upper bands, , i.e., COGNITIVE, RATIONAL or SOCIAL.*

Four operation modes in daily activities

- Behavior selection of daily behavior is done in the states of MODE 1, 3, and 4.
  - *In many cases, behavior selection is done in MODE 1, in which bodily habitual activities are taken unconsciously, SYSTEM 1. with occasional intervention of conscious process, SYSTEM 2, to monitor the outcome of unconscious processes.*
- When there are activities simply executed solely with unconscious processes, SYSTEM 1, behavior selection is done in the state of MODE 4.
  - *Easy to cause problems.*
- The activities performed in the state of MODE 2 have a considerably slow processing speed.
  - *Effective only for limited cases.*

Behavior selection in detail and its dependency on SYSTEM 1 and SYSTEM 2 capabilities

- Actual behavior selection is carried out based on the state of memory that was activated, reconstructed, and reproduced by the environmental perceptual stimuli at that time.
- Behavior selection is carried out as follows:
  - Use the reproduced memory that represents a balanced cooperation among the four processes formed in the past,
  - Use the information from the environment,
  - Estimate the time to the event to happen in the future and/or physical constraints, and then
  - Select the MODE best adapted to the current situation.
- Memory of four processes depends on individual capabilities:
  - Balance between performances of SYSTEM 1 and SYSTEM 2 varies individually because it is impossible to have everybody develop them simultaneously under the processing limitations of brain.

Behavior selection processes and active memory region

There are three situations:

1) Active memory region is largely intact
Processing continues in the chain of SYSTEM 1 and occasionally makes easy conscious choice reasoning from the past memories. – "A" activity dominant

2) Active memory region is affected by conscious activities
Some processing in the chain of SYSTEM 1 becomes un-executable. Then the situation is resolved with the help of predictive conscious choice reasoning from past memories, leading to chain processing of SYSTEM 1.
– "A" activity dominant with timely participation of "B" activity

3) Active memory region is significantly affected
Processing in the chain of SYSTEM 1 can not be continued. Then prediction from past memory is performed as far as time allows by conscious choice.
– "B" activity dominant

- Since SYSTEM 2-A activity has experience in the past, the search of memory is limited and the influence on the active memory region is small.
- Since SYSTEM 2-B activity has not been practiced in the past in many cases, various memory searches are performed and the influence on the active memory regieon is great.

6. MHP/RT: Model Human Processor with Realtime Constraints

MHP/RT: a model of O-PDP (Figure 3, [9])

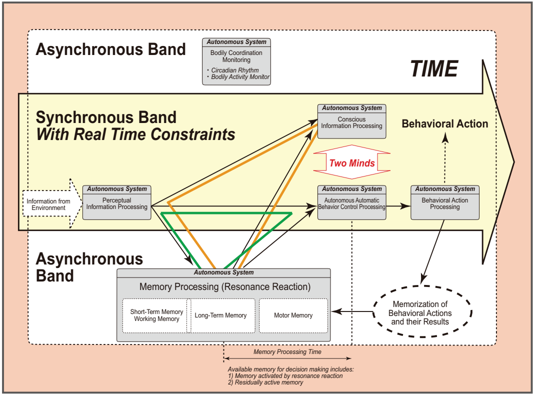

Figure 4: MHP/RT is an engineering approximation of O-PDP having the same philosophy behind MHP by Card, Moran, and Newell [8]. It is capable of simulating people's daily action selections.

Autonomous processing systems of MHP/RT

Working in weak synchronization		
1)	Perceptual Information Processing System	
2)	Conscious Information Processing System	SYSTEM 2
3)	Automatic Behavior Control Processing System	SYSTEM 1-2
4)	Behavioral Action Processing System	SYSTEM 1-1
Working asynchronously		
5)	Bodily Coordination Monitoring System	
6)	Memory Processing System	

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[8] Stuart K. Card, Thomas P. Moran, and Allen Newell. *The Psychology of Human-Computer Interaction*. Lawrence Erlbaum Associates, Hillsdale, NJ, 1983.

[9] Muneo Kitajima and Makoto Toyota. Decision-making and action selection in Two Minds: An analysis based on Model Human Processor with Realtime Constraints (MHP/RT). *Biologically Inspired Cognitive Architectures*, 5:82–93, 2013.

MHP/RT equipped with multi-dimensional memory frames

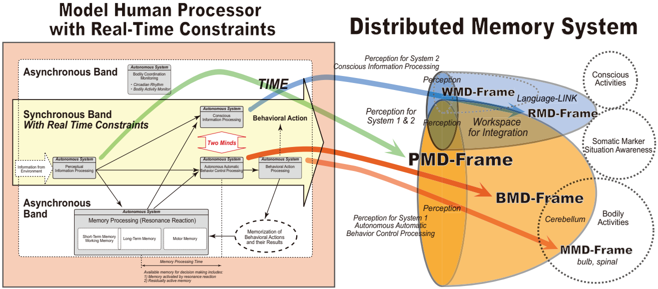

Figure 5: MHP/RT and the distributed multi-dimensional memory frames (Figure 3, [10]). *M*-dimensional PMD is mapped on *N*-dimensional MMD via BMD, RMD, and WMD, i.e., $M \otimes N$ mappings.

[10] Muneo Kitajima and Makoto Toyota. Topological Considerations of Memory Structure. In *Procedia Computer Science, BICA 2014. 5th Annual International Conference on Biologically Inspired Cognitive Architectures*, volume 41, pages 45–50, 2014.

Contents of memory: PMD vs WMD, RMD, and BMD

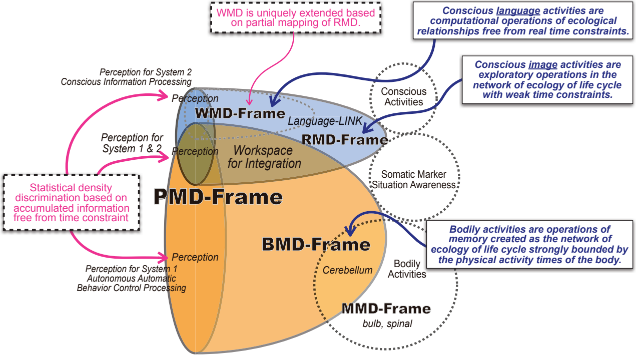

Figure 6: PMD is used for statistical density discrimination. WMD, RMD, and BMD uses computational, exploratory, and search operations, respectively, in the network of life cycle ecology.

Distributed memory system – PMD and MMD

- *PMD (Perceptual Multi-Dimensional) memory frame* constitutes perceptual memory as a relational matrix structure. It collects information from external objects followed by separating it into a variety of perceptual information, and re-collects the same information in the other situations, accumulating the information from the objects via a variety of different processes. PMD-frame incrementally grows as it creates memory from the input information and matches it against the past memory in parallel.
- *MMD (Motion Multi-Dimensional) memory frame* constitutes behavioral memory as a matrix structure. The behavioral action processing starts when unconscious autonomous behavior shows after one's birth. It gathers a variety of perceptual information as well to connect muscles with nerves using spinals as a reflection point. In accordance with one's physical growth, it widens the range of activities the behavioral action processing can cover autonomously.

Distributed memory system – BMD, RMD, and WMD

- *BMD (Behavior Multi-Dimensional) memory frame* is the memory structure associated with the autonomous automatic behavior control processing. It combines a set of MMD-frames into a manipulable unit.
- *RMD (Relation Multi-Dimensional) memory frame* is the memory structure associated with the conscious information processing. It combines a set of BMD-frames into a manipulable unit. The role BMD-frames play for RMD-frame is equivalent to the role MMD-frames play for BMD-frame.
- *WMD (Word Multi-Dimensional) memory frame* is the memory structure for language. It is constructed on a very simple one-dimensional array.

Perception initiates memory activation

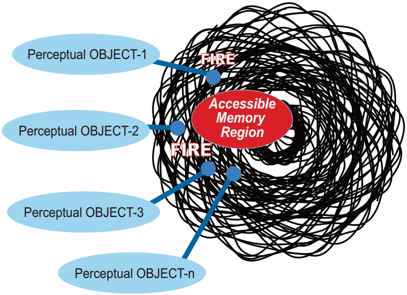

Figure 7: Chain-firing triggered by perceptual stimuli in a cross-networked memory structure (Figure 2, [10]).

[10] Muneo Kitajima and Makoto Toyota. Topological Considerations of Memory Structure. In *Procedia Computer Science, BICA 2014. 5th Annual International Conference on Biologically Inspired Cognitive Architectures*, volume 41, pages 45–50, 2014.

PMD-centered top-down and bottom-up processes

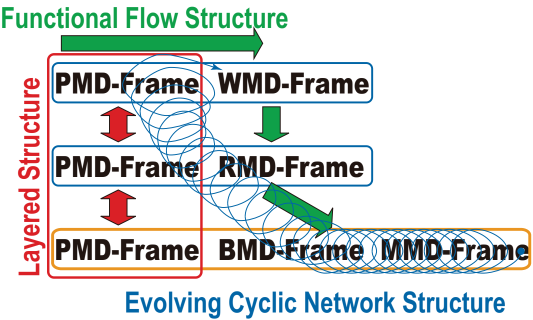

Figure 8: Functional flow structure, layered structure, and evolving cyclic network structure (Figure 4, [10]).

[10] Muneo Kitajima and Makoto Toyota. Topological Considerations of Memory Structure. In *Procedia Computer Science, BICA 2014. 5th Annual International Conference on Biologically Inspired Cognitive Architectures*, volume 41, pages 45–50, 2014.

7. Goal of O-PDP system

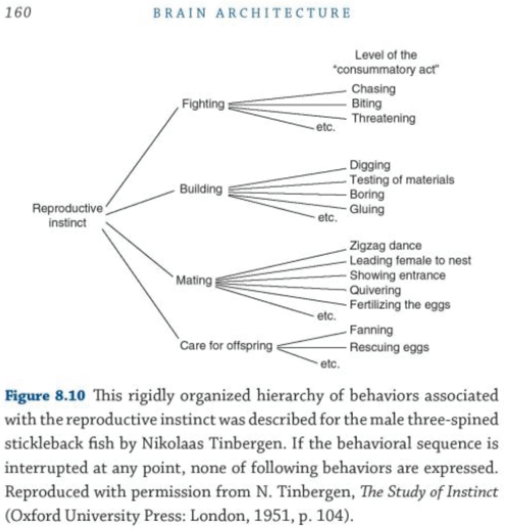
160 BRAIN ARCHITECTURE

Figure 8.10 This rigidly organized hierarchy of behaviors associated with the reproductive instinct was described for the male three-spined stickleback fish by Nikolaas Tinbergen. If the behavioral sequence is interrupted at any point, none of following behaviors are expressed. Reproduced with permission from N. Tinbergen, *The Study of Instinct* (Oxford University Press: London, 1951, p. 104).

Figure 9: There is no ecological evolution of the spinal system [5]

Table 3: Happiness goals [11] and their relation to social layers. +'s denote the degree of relevance of each goal to each layer, i.e., Individual, Community, and Social system, respectively. +++: most relevant, ++: moderately relevant, and +: weakly relevant.

	Happiness	Types	Individual level	Community level	Social system level
1	Target Happiness	The Achiever	+++	+++	+++
2	Competitive Happiness	The Winner		+++	+++
3	Cooperative Happiness	The Helper		+++	+++
4	Genetic Happiness	The Relative	+++	+++	
5	Sensual Happiness	The Hedonist	+++	+++	
6	Cerebral Happiness	The Intellectual	+++	+++	++
7	Rhythmic Happiness	The Dancer	+++	+++	
8	Painful Happiness	The Masochist	+++		
9	Dangerous Happiness	The Risk-taker	+++	++	+
10	Selective Happiness	The Hysteric	+++	++	
11	Tranquil Happiness	The Mediator	+++		
12	Devout Happiness	The Believer		+++	++
13	Negative Happiness	The Suffer	+++	++	
14	Chemical Happiness	The Drug-taker	+++		
15	Fantasy Happiness	The Day-dreamer	+++		
16	Comic Happiness	The Laugher	+++	+++	
17	Accidental Happiness	The Fortunate	+++	+++	+++

[11] Desmond Morris. *The nature of happiness*. Little Books Ltd., London, 2006.

8. Weak synchronization

Chaining discrete functions to form a procedure

In order for an O-PDP system to accomplish its goal, i.e., one from Table 3, functions performed in one of four MODEs have to be chained (combined each other) to form a procedure.

- A mechanism is needed for establishing a chain between functions that exist quasi-independently and discretely.
- An O-PDP system is composed of autonomous elements in a band-structure, and the processes carried out in the respective bands are synchronized each other to form a function.
- Synchronization between autonomous elements is incomplete weak synchronization that implicitly assumes the circularity of the existence environment – autopoiesis.

Weak synchronization

- O-PDP system is created as a developed form of naturally formed energy circulation.
- Weak synchronization is achieved as the outcome of autonomous and adaptive activities for survival, and its procedure is different in each synchronization case.
- Essentially each element perceives the behavior of the previous elements in the chain as a signal and acts as a signal to the activity of the elements of the subsequent chain.

The way of synchronization between each element

- Each element of the O-PDP system plays a certain role in achieving the overall goal that the whole O-PDP system is about to achieve.
- However, its role is not determined from the beginning but it exists only as a result of each element's own efforts to sustain since it started its activity.
- The way of synchronization between each element is incidentally determined, and the synchronization itself is not deterministic but incomplete weak synchronization.

Path proliferation and convergence in O-PDP

- Various combinations of functional chains between parallel processes occur, causing path proliferation of the network.
  - This is because there exist time relativity due to network circularity and fluctuation in processing in the behavioral ecology network of the O-PDP system.
- When the recall rates of specific paths become higher, proliferation along these paths are suppressed to centralize the activations on these paths thereafter.

Maintaining continuity of activities in O-PDP

- A function which is activities carried out in the spatio-time dimension in a MODE under weak synchronization among bands is connected to another using adjustable range for connection.

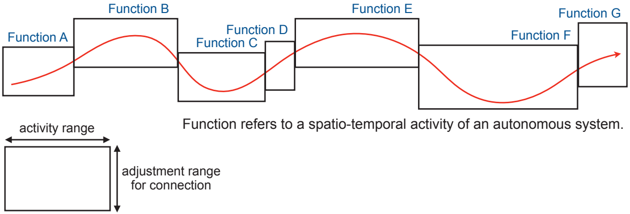

Figure 10: Successive functions are connected within the adjustable band in the spatio-time dimension.

Stability in O-PDP system

Why is reasonable stability maintained in the uncertain procedure dependent on the autonomous reaction of the O-PDP system?
Bacause $\cdots$

- A parallel distributed processing system is formed in the nonlinear hierarchically structured bands as a method of executing problem processing.
- Perceptual input is used in three bands (Figure 6) and shared.
- Time constraints from the environment can be satisfied by fluctuations in the characteristic times of autonomous activities in respective bands.

Adaptability in PIM

Adaptability in PIM:

- Perception: ability to recognize situations with high precision in advance
- Motion: ability to carry out various exercise paths
- Interneuron: ability to make appropriate routing
- Comprehensive ability: ability as a correlative combination of abilities in P, I, and M

9. Neoteny

Neoteny: Development of perception, interneuron, and motor mechanisms in the individual environments

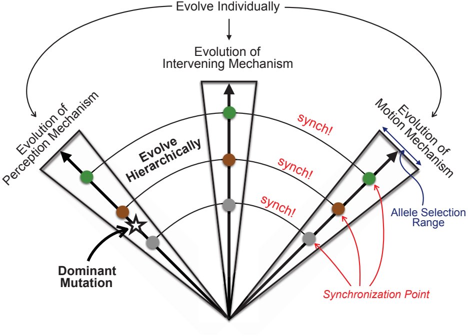

Figure 11: Hierarchical evolution by successive re-synchronization among perceptual, intervening, and motor mechanisms (a detailed explanation of Figure 2).

Neoteny: Development of perception, interneuron, and motor mechanisms in the individual environments

- Components of O-PDP develop autonomously.
- Mutations also occur for each component.
- Development of O-PDP occurs on the basis of the body plan that regulates the flow of inter-component chains and the order of synchronization between components.
- Therefore, when a change occurs in one of the components, the influence extends to the entire component and the entire structure in various forms.

When a certain autonomous mechanism develops by a dominant mutation, the synchronization mode between the autonomous mechanisms is readjusted, and mutations of other autonomous mechanisms are promoted.

Change of active bands – followed by route generation, selection, and extinction

- Changes of active bands occur due to environmental changes or due to ecological changes of the competitive group.
- Changes are recognized when:
  - Activity constraints become stronger.
  - Noticing being freed from the activity constraints in continuous stable activity by accidental changes of own behavior or changes in perceptual information.
- Changes of active bands cause changes in the route of the ecological network, but there is no fixed way of changing the route, so long as it is persistent.
- After that, route generation, selection and extinction are repeated, and overall optimization is promoted from the viewpoint of overall circulation efficiency.

Development through selecting efficient splicing routes

- The development of the O-PDP system mechanism follows discrete paths by splicing rather than continuous.
- Conditions for selecting efficient splicing routes:
  - The problem or goal is clearly recognized.
  - Noticing that multiple routes leading to the goal are available.
  - Either SYSTEM 1 or SYSTEM 2 takes the initiative at the appropriate time to search for efficient routes to the goal.
  - A variety of solutions are possible because they depend on the balance of SYSTEM 1 and SYSTEM 2 at that time.

Neoteny and splicing

Non-linear development in neoteny interacts with non-linear development in splicing to create behavioral traces in the real environment, with the following features:

- Manifestation of dual processes, i.e., conscious processes, SYSTEM 2, and unconscious processes, SYSTEM 1.
- Exponential differences in characteristic times of active bands.
- SYSTEM 1-1 and SYSTEM 1-2 are related to each other and perform functionally distributed parallel activities, whereas SYSTEM 2 forms serial and unified action paths.

10. Concluding remarks

What happens in awake state:

- In awake state, when perceptual information flows in, the following occurs:
  1. PMD memory is activated,
  2. Activity propagates to Object of RMD,
  3. Activation center is formed at Object, and
  4. With rewards, the activation center becomes more robust.
- The correlation between RMD (SYSTE 2 image) and BMD (SYSTEM 1-2) affects the strength of the activation center, resulting in competition of activation centers on RMD.
- Afterwards, the trajectory of the center on the RMD network is affected by: 1) symbols in WMD, 2) time constraints, 3) the degree of habituality, and follows one of the four MODEs.
- Mind is like a typhoon that moves around the RMD network, and its center is symbolized as a virtual vague existence (a world without centers) where diverse energy gathers.

Reductive understanding vs. inductive understanding

- Although the appearance and relationship of the structural formation of the brain's biological mechanism can be described in a diagram and described in a reductive manner, it is impossible to predict behavior directly from there.
- Actual behavior is a collection of dynamic reflection phenomena under time constraint. Therefore, in order to understand it, it is necessary to rethink them from the viewpoint of finding similarities with the mechanisms generating various dynamic phenomena in the natural world and then inductively integrate them.

APPENDIX

A. Cognitive Chrono-Ethnography

CCE Steps

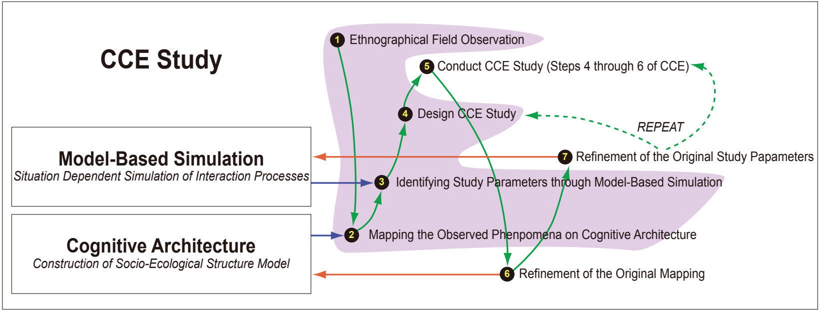

Figure 12: The CCE procedure.

A CCE Study: Slow self-paced navigation (Chapter 6 [12])

- With the focus of action selection processes involved in slow self-paced navigation, this chapter illustrates a case study that adopted the CCE methodology to investigate how elderly people use guide signs at train stations when they have to transfer lines, in addition to use some facilities such as restrooms, lockers, elevators, telephones, and so on. This study was sponsored by a train company in Japan and had the purpose of gaining insight for improving the usability of guide signs at train stations for elderly passengers.

[12] Muneo Kitajima. *Memory and Action Selection in Human-Machine Interaction. Wiley-ISTE, 2016.*

Fast externally-paced navigation (Chapter 7 [12])

- With the focus of action selection processes involved in fast externally-paced navigation, this chapter illustrates a case study that adopted the CCE methodology to derive information necessary for safe and enjoyable driving for drivers while just driving. Note that this is a time critical situation where System 2 Before Mode and System 1 Before Mode should be appropriately coordinated along the information provided externally e.g., through a car navigation system of a human navigator. The study was designed in such a way that participants as drivers should perform event-based navigation, and have aided to conduct otherwise impossible driving in System 2 Before Mode, i.e., anticipation-based navigation, by "timely" provided "appropriate" information.

Designing for future needs (Chapter 8 [12])

- This chapter describes how people's future needs are derived by applying CCE introduced in Chapter 5. CCE assumes that people select their next behavior to maximize their satisfaction for a given behavioral needs by appropriately coordinating available cognitive resources. CCE starts by defining critical parameters for understanding people's behavior by considering the nature of behavior selection processes in the field in question, and then designing ethnographical field observations. The participant's behavior is recorded, followed by a series of structured retrospective interviews. Analysis of the interview results aids in developing models of present behavior selections and their chronological changes in the past which should trace the changes in people's behavioral needs and the structure of satisfaction. This chapter claims that these models should serve as defining future needs of persons who would follow the same developing paths with a certain amount of time delay.

Understanding tourists' *in situ* behavior: A CCE study of visitors to a hot spring resort [13]

Hot spring resorts are popular tourist attractions in Japan. However, little is known about why these resorts are popular destinations. This paper introduces a methodology, Cognitive Chrono-Ethnography, which is an ethnographical field study that is designed through the consideration of cognitive constraints. The method serves as an application to understand tourists' behavioral selections in terms of their chronological development. This study applies the method at a hot spring resort, Kinosaki-Onsen, located in the western part of Japan. Forty-three groups of study monitors with different visiting styles participated in the study. Each group arrived at and were asked to tour Kinosaki-Onsen. They were instructed to carry a GPS and a digital camera for recording their activities, as well as to write brief notes concerning their activities. We conducted interviews the next day with the recorded data. By analyzing the results of the interviews, we identified six types of tourist activities including: bathing, staying, eating, exploring, touring, and shopping. Each activity had its own characteristic behavioral pattern. Therefore, the typology derived is useful for designing services that match individual activity patterns.

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[13] Muneo Kitajima, Hirotsugu Tahira, Sachi Takahashi, and Toshiko Midorikawa. Understanding tourist's *in situ* behavior: a Cognitive Chrono-Ethnography study of visitors to a hot spring resort. *Journal of Quality Assurance in Hospitality and Tourism, 12:247–270, 2012.*

B. Application of O-PDP to a variety of domains

Application of O-PDP to a variety of domains

- Multiplicity of personality from the viewpoint of environmental adaptation
- Influence of particular structure of language in WMD on RMD, e.g., the structural difference of the RMD networks in "hierarchical" French vs. "flat" Japanese
- Behavior analysis based on understanding of language development (colloquial → literary word, surface expression → structure expression)
- ...