Dynamics of consciousness-emotion interaction: an explanation by NDHB-Model/RT

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Abstract Traditional cognitive sciences have not treated human behavior as the result of intense interaction between consciousness and emotion. Rather, these two functions have been studied separately. However, in the existing internet era, it is urgently necessary to develop unified theories that can deal with the dynamics of consciousness-emotion interaction in order to design appropriate information systems. This paper explains the interaction based on an architecture model we have been developing as a candidate for such unified theories, the Nonlinear Dynamic Human Behavior Model with Real-Time Constraints, **NDHB-Model/RT**, presented at CogSci2007 [3] and CogSci2008 [1,2]. NDHB-Model/RT represents consciousness as one-dimensional linear operations (language) and emotion as a hydrodynamic flow of information in multi-dimensional parallel operations in the neural networks. NDHB-Model/RT also has autonomous memory systems that mediate between consciousness and emotion to display their dynamic interactions. Model Human Processor with real time constraints, **MHP/RT**, is proposed as the simulation model on NDHB-Model/RT.

Features of behavioral decisions

The brain consists of the following three non-linearly connected layers. Behavioral decisions are made by integrating the results of operations of these three layers.

C layer: Conscious state layer
A^2BC layer: Autonomous-automatic behavior control layer
B layer: Bodily state layer

The bodily state layer prioritizes the 17 behavioral goals presented in Fig. B. The other two layers interact with each other in order to derive the next behavior that should satisfy the highest prioritized goal. In normal situations in our daily life, temporal changes in the environment impose the strongest constraint on the decision of the next behavior, and thus the A^2BC layer plays a more dominant role than the C layer in organizing behavior.

The next behavior is determined by extracting objects from the ever-changing environment and attaching values to them according to the degree of the strength of the resonance with what is stored in the autonomic memory system. This is followed by deliberate judgement by using the knowledge associated with the highly valued objects. The former is controlled by the processes in the A^2BC layer; the latter, by the processes in the C layer.

Interaction between consciousness and emotion

The processes in the A^2BC layer and those in the C layer are not independent. Rather, they interact with each other very intensely in some cases but very weakly in other cases. We investigate this issue in more detail below.

Onset of consciousness. With the onset of arousal, the sensory organs begin to collect environmental information. This information flows into the brain, and the information flow volume grows rapidly. As the information flow circulates in the neural networks, the center of the flow gradually emerges. It corresponds to the location where the successive firings of the neural networks concentrate. At this time, the center of information flow induces activities in the C layer via the cross-links in the neural networks.

Conscious activities. Figure 1 depicts the state of the brain when consciousness starts working. The location of consciousness is indicated as a dot in the C layer. In many cases, the working of consciousness includes such cognitive activities as comprehension of self-orientation and an individual's circumstances. When decision making is needed for the current situation, the location of consciousness could move. The direction of movement is determined by the information needs at that time. It could move either in the direction in which the initial information is deepened (left in the figure) or to the direction in which the initial information is widened (right in the figure). The density of information would change depending on how far the center of consciousness moves. However, the location of the consciousness would not move when carrying out a routine task.

Emergence of emotion. After the onset of consciousness, a new thread of information coming into the brain via the sensory organs triggers successive firing within the neural networks. This causes a new information flow in the brain that reflects past experience that resonates with the input information. If there is a discrepancy between the new information flow (the dotted line in the figure) and the existing information flow (the solid line in the figure), emotion emerges. Emotion works to reduce the amount of discrepancy.

Determination of next behavior. When the A^2BC layer works continuously within its capacity, consciousness does not interfere with the working of the A^2BC layer but monitors the individual's behavior, prepares for the next behavior, and/or ponders issues that come to mind. However, if the A^2BC layer has difficulty in determining the next behavior, the C layer takes over and determines it. The following depicts the flow of the processes that would happen (see Fig. 2).

1. Consciousness determines the next behavior by considering the current state of emotion and the self-recognition.
2. Consciousness tunes the orientation of the sensory organs in preparation for initiating the next behavior just determined.
3. Consciousness commands initiating the next behavior.
4. The behavior results in changes in the information flow.
5. The direction of emotion changes.
6. The new state of emotion affects the process of determining the next action.

Synchronization between the C layer and the A^2BC layer: Model Human Processor with Real Time Constraints

The most important assumption of the NDHB-Model/RT is that the human brain works under real-time constraints governed by the environment, largely uncontrollable from the brain. We assume that the C layer and the A^2BC layer operate together in order to determine the next behavior. However, as described above, the interaction between them could be weak or strong, depending on the situation. There thus needs to be a synchronization mechanism for them to work together appropriately.

We suggest that the visual-frame reconstruction process in the C layer should be used for establishing synchronization between the C layer and the A^2BC layer. As depicted in Fig. 3, the C layer predicts the representation of the visual frame that should appear in the future and uses it for synchronization. When the A^2BC layer mainly controls the behavior, the visual-frame rate would be around 10 frames per second, and the C layer would monitor the self-behavior by occasionally matching the expected visual frame and the real visual frame in the A^2BC layer. In contrast, when the C layer mainly controls the behavior, the rate would become lower and vary depending on the interest of consciousness. For the former situation, the visual-frame density is high but the information density is low; for the latter situation, the visual-frame density is low but the information density is high. This explanation is consistent with the well-known Newell's Time Scale of Human Action [4].

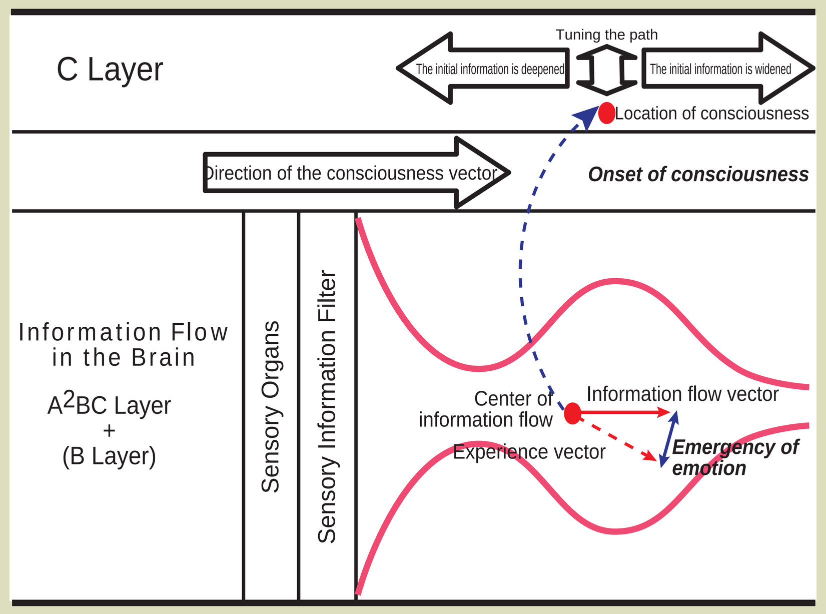

Figure 1: Onset of consciousness and emergency of emotion.

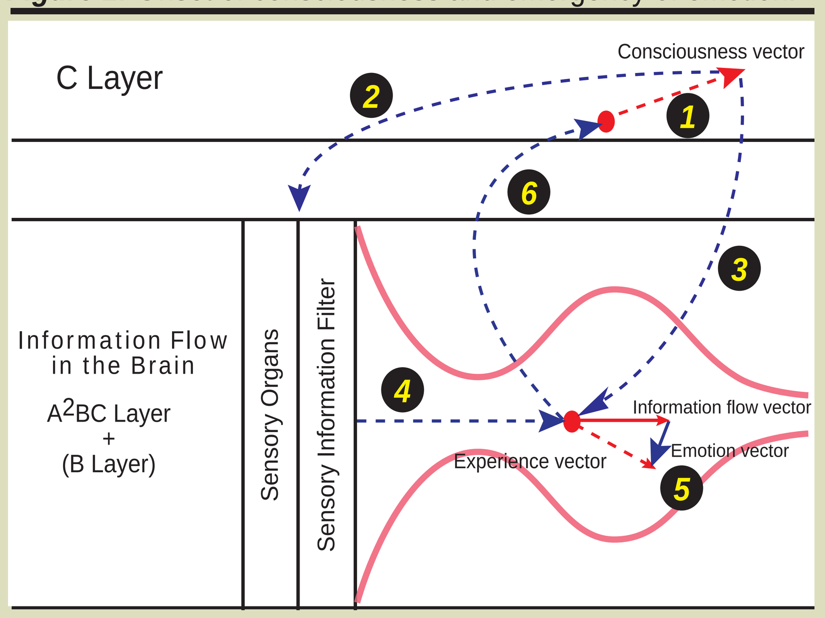

Figure 2: Determination of next behavior.

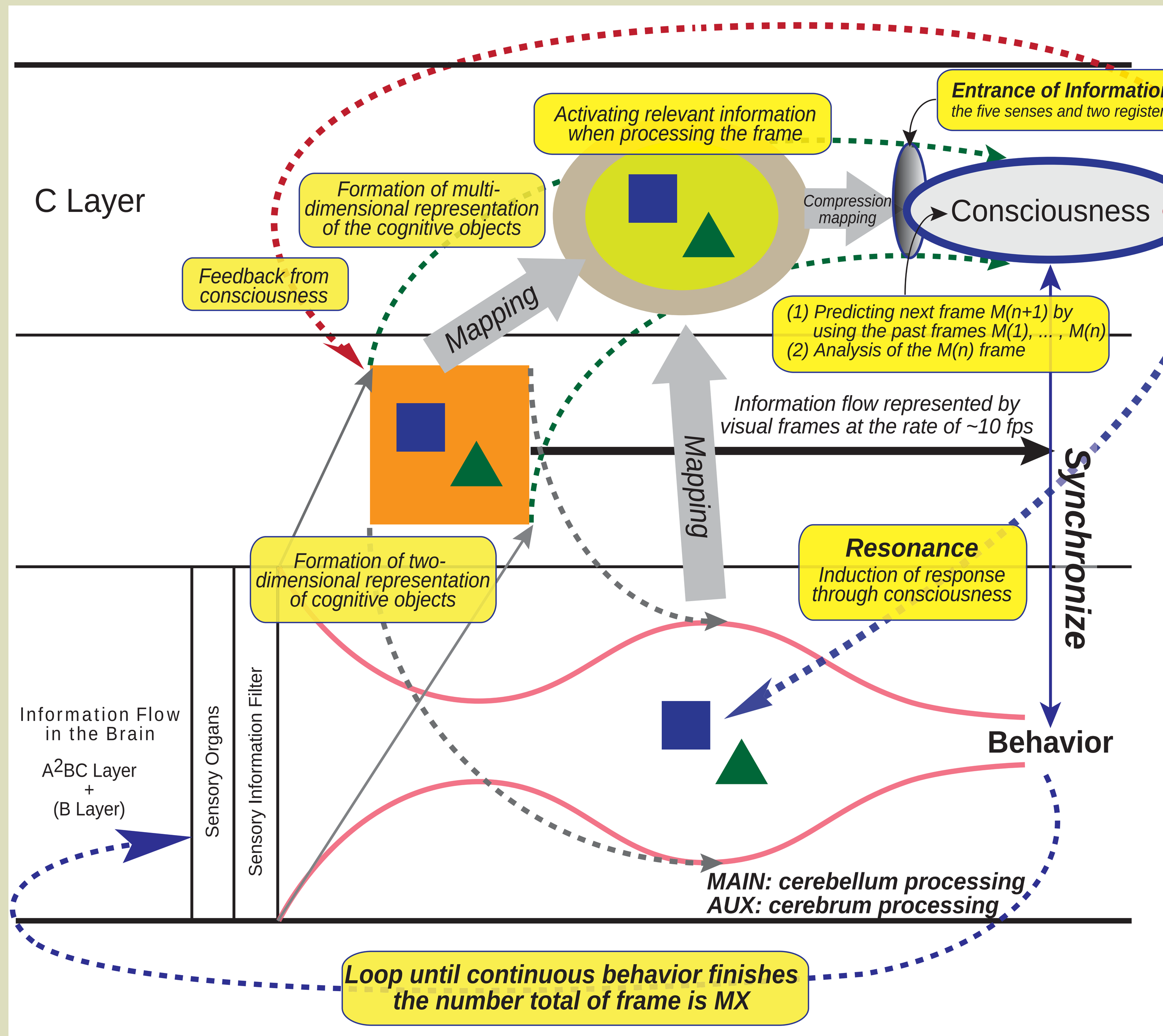

Figure 3: Model Human Processor with Real Time Constraints, MHP/RT.

Nonlinear Dynamic Human Behavior Model with Real-Time Constraints (NDHB-Model /RT)

Living organisms, including human beings, act autonomously. The living environment on the Earth is a field constructed through interactions among the living organisms in a variety of ways. The Earth's environment changes continuously in a one-year fundamental cycle. In order to attain stability in the ever-changing environment, which incorporates the Earth and the other living organisms, living organisms have developed their own autonomous control systems.

The whole universe of complexly interconnected living organisms thus constructed can be called "an organic self-consistent field." Figure A depicts such a field from the viewpoint of the information structure. The autonomous living organisms act by mapping the information structure shown in Fig. A onto their brains in their evolution. The nonlinear dynamic human behavior model with real-time constraints represents an organic self-consistent field as a model.

It consists of three fundamental nonlinear constructs that correspond to the information structure of Fig. A.

1. **Brain Information Hydrodynamics (BIH):** BIH deals with information flow in the brain and its characteristics in the time dimension (see [1] for detail).
2. **Structured Meme Theory (SMT):** SMT deals with empirical effectiveness of information and its range (see [2] for detail).
3. **Maximum Satisfaction Architecture (MSA):** MSA deals with how autonomous systems achieve goals under constraints (see [3] for detail).

BIH, SMT, and MSA jointly define constraints for actions as follows. The phenomena that emerge in the human society are the results of the actions that each human's autonomous system takes in order to maximize satisfaction and happiness (MSA) under the constraints defined by BIH and SMT. Figure B depicts the brain mechanism according to the proposed model. The brain consists of memory that functions as an autonomous organ and bodily activity control that functions as a somatic organ.

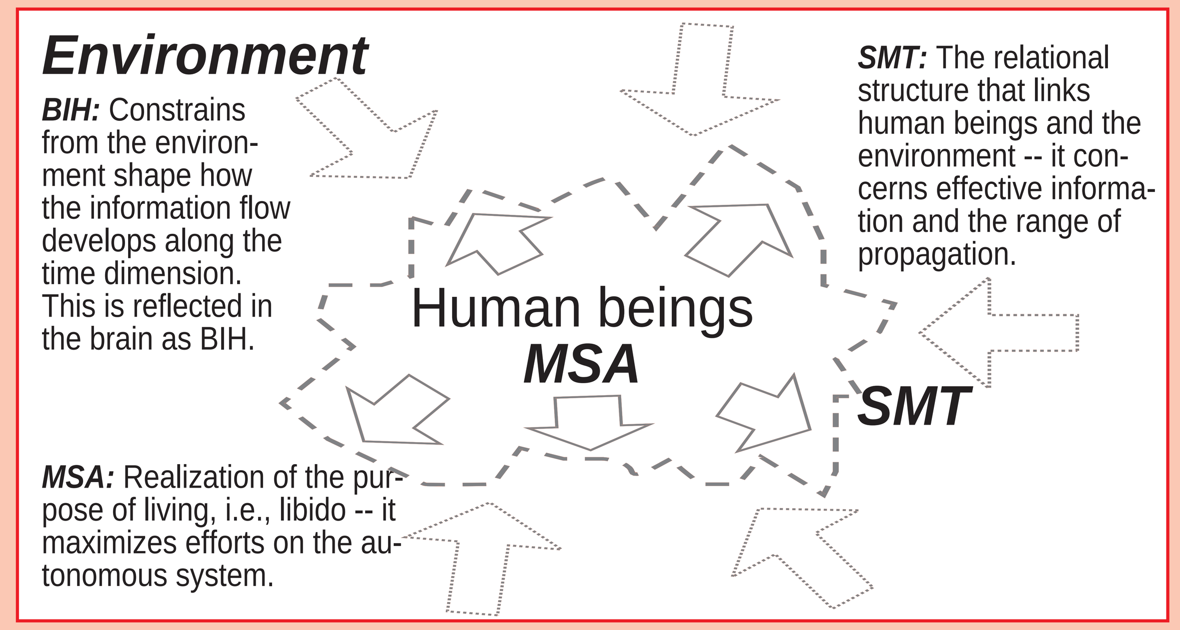

Figure A: Three fundamental constructs that define the nonlinear dynamic human behavior model with real-time constraints.

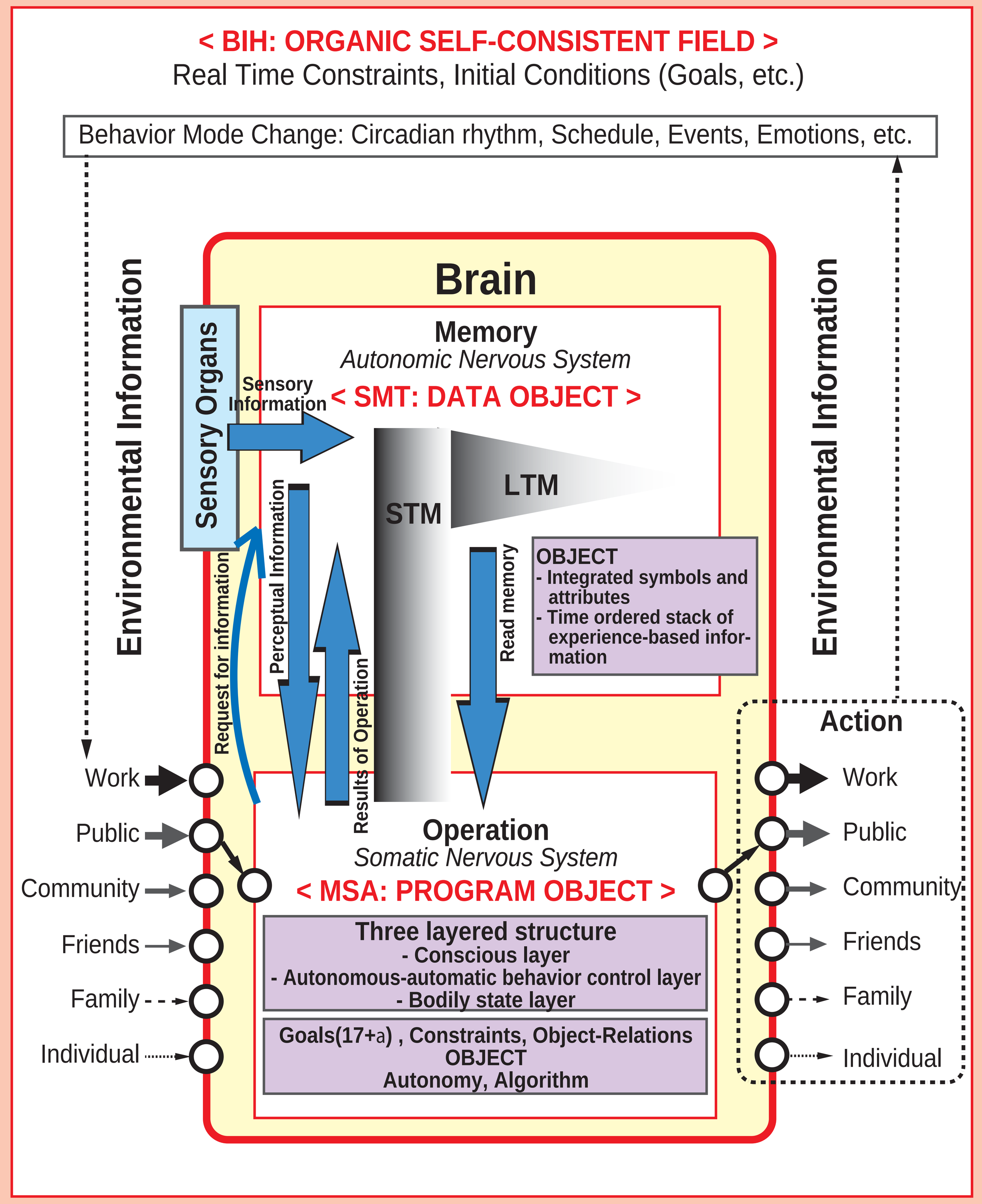

Figure B: Mechanism of the brain explained by the NDHB-Model/RT.

References

[1] Kitajima, M., Toyota, M., & Shimada, H. (2008). Model Brain: Brain Information Hydrodynamics. Proceedings of the 30th Annual Meeting of the Cognitive Science Society, 1453.

[2] Toyota, M., Kitajima, M., & Shimada, H. (2008). Structured Meme Theory: How Is Informational Inheritance Maintained? Proceedings of the 30th Annual Meeting of the Cognitive Science Society, 2288.

[3] Kitajima, M., Shimada, H., & Toyota, M. (2007). MSA:Maximum Satisfaction Architecture: A Basis for Designing Intelligent Autonomous Agents on WEB 2.0. Proceedings of the 29th Annual Meeting of the Cognitive Science Society, 1790.

[4] Newell, A. (1994). Unified Theories of Cognition. Harvard University Press.