

Using Robot Science to Model Advanced Cognitive Disorders in Humans

Junichi Takeno*

Robot Science Laboratory, Computer Science, Meiji University, Kawasaki, Japan

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Introduction

Besides a physical impairment of the body originating from a physical injury to the human brain, we have also become able to infer that it is also possible for a mental impairment to originate from a mental trauma to the human brain. The famous controversy between Sigmund Freud and Pierre Janet over the condition of hysteria is an example of such a mental impairment [1]. Also, during World War I, soldiers who were helplessly trapped in their trenches with artillery shells bursting around them suffered the trauma which later came to be known as shell shock. There is a theory that this condition occurred due to the fact that their brains were subjected to some sort of psychological damage [2,3]. Severe cases of post-traumatic stress disorder (PTSD) have been reported among soldiers who were stationed in Vietnam and Iraq [4]. Furthermore, individuals who have undergone terrible abuse during their childhood years have been reported to develop multiple personalities, a condition known as dissociative identity disorder (DID) [5,6].

Now the first problem that arises is the question of whether or not a human "mental state" exists. Some researchers state that "no mental state exists;" while others maintain that "there is a mental state." The former researchers claim that the issue originates in materialism, while the latter ones state that their thinking is easily understood as originating in phenomenology. Even now this ongoing controversy is very active [7,8].

Although this controversy is important, if the validity of either of the claims cannot yet be determined, it may be necessary to proceed with this study by taking one of the positions. The author believes that the subjective phenomenon of the self is undeniable, and for that reason, takes a stand with the viewpoint of phenomenology.

From that standpoint, when we further consider the foundation of the subjective phenomena of humans, we can focus on the neurons in the brain and their networks. And from within the brain, these neurons and networks extend further to those that reach each parts of the body. When speaking here of subjective phenomena, the author is including such attributes as human consciousness and the mind, sentience, emotions and feelings, and self-awareness. From this observation, it can be said that the subjective phenomena of humans result from the fact that these neurons and their networks are exchanging information between the brain and the body. The author does not intend to assert that this explanation accounts for everything, but rather that it is an attempt to focus on the salient points.

The advantage of taking this position is that it is encompassed within the claims made by those advocating the materialism viewpoint. The reason for this is because the thinking that it is the information that is flowing in the neurons and their networks that comprises the subjective phenomena, and the fact that there is no substance involved, is compatible with the claims of materialism. In other words, the lack of any involvement of substance can positively affirm the subjective phenomena of humans.

Incidentally, neurons and their networks can now be described in mathematical terms, and it is also possible to describe them as a computer program. This assertion takes the subjective phenomena of humans, that is, the foundation of the spirit, to be a program. However, although this discussion is directly connected to the idea that a computer is running a program, it is obvious that the content of that program cannot describe the subjective phenomena of humans. This is because some subjective phenomena of humans, that is, self-referential content, self-consciousness and self-awareness, cannot be described as conventional program yet. Therefore the author and his research group have developed programs with specialized neural networks that meet these requirements.

Development of Neural Networks with Self-referential Functions

The author calls this developed neural network a Module of Nerves for Advanced Dynamics, or a MoNAD [9]. The structure of the MoNAD comprises two coupled recurrent neural networks. One of these neural networks calculates the information input from lower layers by neuro-processing and outputs the result to the lower layers. This is also called the primary reaction system. The second neural network has the function of cycling information synchronized with the intermediate layers of the primary reaction system. This is called the secondary reaction system. The secondary reaction system also has input and output terminals for exchanging information with the upper layer system. The MoNADs can be considered to be independent modules that communicate information with each other to the lower and upper layer systems. The primary system and the secondary system convey the lower layer information to the upper layers, and the secondary system conveys upper layer information to the lower layers. In other words, the MoNADs function within the exchange of bottom-up and top-down information.

The MoNAD can be explained as having self-referential functions by means of a mechanism in which the observation target of the secondary system is the reaction itself of the primary system [10].

The reason for this is that the primary reaction system and the secondary reaction system share a group of neurons, and because they are synchronized as well, the secondary system can function as a metalogic circuit for the primary system.

And in addition to hierarchically linking a large number of

*Corresponding author: Junichi Takeno, Robot Science Laboratory, Computer Science, Meiji University, PO Box 214-8571, Higashimita 1-1-1, Tama-ku, Kawasaki-shi, Kanagawa, Japan, Tel: 044 934 7454; E-mail: juntakeno@gmail.com

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MoNADs, the author has also connected the input and output sections of the lowest layer MoNADs to sensors and actuators respectively inside and outside of the body. The system composed of these multi-layered MoNADs is named a conscious system. The system is called conscious based on the fact that it is composed of MoNADs with self-referential functions. For example, if the MoNAD is capable of achieving “watch and imitate behavior,” the primary system uses information from the sensors to detect that “the other is moving forward,” and the primary system outputs information that “I will move forward.” And the secondary system gives a representation of the self-referential information that “the other is moving forward, and I am moving forward.” Representation means the information that indicates the cognitive result. This is the firing of groups of neurons. The function of being simultaneously cognitive of the behavior of the other and the behavior of the self is an important requirement for the function of “consciousness,” and it also encompasses the self-referential functions.

As described so far, the reader should readily understand that by using a conscious system comprised of MoNADs, a significant step forward can be taken toward achieving a robot with higher cognitive functions. The author and his research group are continuing to attempt this. Some examples of their studies are the “Robot that recognizes the unknown” [11], “Self-aware robot” [12,13], “Robot that represents pleasant and unpleasant feelings and self-evolves” [14].

Now, I will explain how the conscious system can explain the states of “unconsciousness” and “consciousness.” However, since there is a possibility that these two terms might be misunderstood, they are paraphrased respectively as “subconscious” and “explicit consciousness.”

A misunderstanding can occur with the former term unconsciousness because it may generally have a variety of meanings which may include losing consciousness or falling into a coma. If the latter term is used, not only can it explain the meaning of the former variety of terms, it is also possible to easily explain the functions of consciousness as having two states. In other words, explicit consciousness means “to recognize that one is conscious of the self” that is, to be capable of self-referential consciousness, while the subconscious refers to consciousness that is not self-referential. Since the MoNAD basically has self-referential functions, it is the foundation of explicit consciousness. Also, conventional neural network system that does not have the MoNAD structure is the foundation of the subconscious. Based on this theory, the firing of the neuron groups that represent the self and the synchronized functioning MoNAD groups can explain that the consciousness that humans possess is in fact the “consciousness that is made explicit.” For other functioning sections, even if there are MoNADs, those sections are the “subconscious” when looking at the system in its entirety.

Modeling of DID using MoNADs

The author and his research group have already embarked on creating a model for post-traumatic stress disorder (PTSD) using MoNADs [15]. It is a conscious system with an input and output section interfacing with the external environment. The main system consists of a reason section A, emotion & feelings section EF, association section H, and episodic memory section EM. The sections other than EM consist of one or more MoNADs. Section A provides the representation of subjects that are distant from the body such as those captured through sight and hearing, and also outputs information to the actuators such as the hands and feet. Using the information from sensors on the surface and inside the body as input values, EF represents “pleasant and unpleasant” feelings. Information from A is also input to EF. The role of H is to

mutually communicate information between A and EF. In this model, when a new event is experienced, G is generated as a new association section for connecting the information that co-occurred at A with the information at EF to develop the conscious system. The conscious system will generate a new G whenever a new event is experienced.

At this time, G is typically positioned at a lower layer of H. In other words, it is possible for G to get references from H, but the reverse is very difficult. This means that everything experienced by the conscious system becomes the association section that is structured at a lower layer of H.

In this model for PTSD using the conscious system, if G experiences the representation of a strong unpleasant feeling, that G can be constructed so that a route referenced from H that is positioned in a lower layer of H temporarily becomes unstable or that it closes. The former approach represents the symptoms of PTSD, while the latter represents the symptoms of DID. At this time, H becomes the representation of the self as the main personality, and G is the representation of an alter personality that is included in the same conscious system.

Conclusion and Observation

The author and his research group have already built a conscious model that causes the symptoms of PTSD. Based on that model, we are currently developing a conscious model that causes the symptoms of DID. Is it simply a frivolous topic to consider causing a robot to suffer a serious mental illness? No, it is not. It should also be noted that the consideration of the rational process that is obtained in the course of building this model as a neural network using MoNADs can also provide important guidelines for brain science studies. It is obvious that we have a much longer road ahead in our quest toward elucidating the truth. However, by building a single model, we believe that we can proceed toward gaining a deeper understanding of the principles and functions of mental illness, and that the knowledge obtained from our study should suggest the best approaches for treating these disorders. In addition, this will also enable a consideration of the potential vulnerabilities of the human brain in light of its ability to always create the best intelligence. Currently, we are working on the problem of why memory is disassociated in DID.

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