The Cognitive Mechanisms and Formal Models of Consciousness

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ABSTRACT

Consciousness is the sense of self and the sign of life in natural intelligence. One of the profound myths in cognitive informatics, psychology, brain science, and computational intelligence is how consciousness is generated by physiological organs and neural networks in the bran. This paper presents a formal model and a cognitive process of consciousness in order to explain how abstract consciousness is generated and what its cognitive mechanisms are. The hierarchical levels of consciousness are explored from the facets of neurology, physiology, and computational intelligence. A rigorous mathematical model of consciousness is created that elaborates the nature of consciousness. The cognitive process of consciousness is formally described using denotational mathematics. It is recognized that consciousness is a set of real-time mental information about bodily and emotional status of an individual stored in the cerebellums known as the Conscious Status Memory (CSM) and is processed/interpreted by the thalamus. The abstract intelligence model of consciousness can be applied in cognitive informatics, cognitive computing, and computational intelligence toward the mimicry and simulation of human perception and awareness of the internal states, external environment, and their interactions in reflexive, perceptive, cognitive, and instructive intelligence.

1. INTRODUCTION

Consciousness is one of the central cognitive functions of the brain and the natural intelligence. Studies on consciousness can be traced back to as early as Aristotle's era, when the dualism treats human beings as the body and soul or the brain and mind problems (Dennett, 1991; Kihlstrom, 1987; Leahey, 1997; Solso, 1999; Wilson & Keil, 2001). Consciousness is the basic characteristic of life and the mind, which is the state of being awareness of oneself, of perception to both internal and external worlds, and of responsive to one's surroundings.

A variety of doctrines on consciousness are developed in psychology and cognitive science (Coaen et al., 1994; Leahey, 1997; Solso, 1999). John Locke (1632-1704) perceived that a major

function of consciousness is to form a personal identity by linking past and present events to ourselves. James (1890) described consciousness as a constantly moving stream of thoughts, feelings, and perceptions. Kihlstrom (1987) identified that consciousness monitors the self and the environment, and controls thought and behavior (Kihlstrom, 1987). Dennett (1991) proposed that consciousness, our sense of self and intentionality, stems from the collective effect of low-level biological and physiological processes (Dennett, 1991). Lefton et al. (2005) perceived consciousness as the general state of being aware of and responsive to events within ourselves and in the environment (Lefton, 2005). Yingxu Wang and his colleagues developed the theory of the Layered Reference Model of the Brain (LRMB) (Wang et al., 2006), which reveals that consciousness is a collective state at the perception layer of the 7-layer LRMB model such as the sensation, action, memory, perception, metacognition, inference, and cognition layers from the bottom-up. The latest advances at Wang`s laboratory have pinpointed the Conscious Status Memory (CSM) in the cerebellum (Wang, 2012d).

Definition 1. *Consciousness* is a collective mental state of self awareness that represents the bodily and mental status and their relations to the external environment, which is inductively generated or synthesized from the levels of metabolic homeostasis, unconsciousness, subconsciousnes, and consciousness from bottom-up.

According to the LRMB model, consciousness is one of the cognitive processes of perception at Layer 4 (Wang et al., 2006) as illustrated in Figure 1. Consciousness is closely coupled with attentions, motivations, emotions, attitudes, imagination, sense of space, and sense of motion at the same layer. It is supported by lower layer functions such as those of the sensation, action, and memory layers. It also intensively interacts with other higher layer life functions and mental processes in the brain. Therefore, to a certain extent, consciousness may not be separately studied without considering the impact and interactions of other cognitive processes, particularly the attention and sensation processes, when the brain is perceived as an extremely intricate system.

How is the abstract consciousness generated based on neural structures and physiological organs in the brain? It is one of the profound myths in cognitive informatics, cognitive psychology, brain science, cognitive computing, and intelligence science. Consciousness is a type of special cognitive information and a part of the natural intelligence. According to Wang's Matter-Energy-Information-Intelligence (MEII) model (Wang, 2002a, 2003; Wang & Wang, 2006), the *natural world* is a dual encompassing both the concrete *physical world* and the perceived *abstract world*. In the MEII model, the abstract world modeled by information possesses interesting properties and constrains by special laws entirely different from those of the physical world (Wang, 2006, 2009a). Because the essence in the abstract world for human mental processes is information, the properties and laws that the brain and mind obey are those of informatics (Wang, 2006), denotational mathematics (Wang, 2007a, 2008c, 2009c), logic, and abstract intelligence (Wang, 2009a). Therefore, in a certain extent, the MEII model indicates that both information and human mental processes are naturally abstract mathematical entities.

This paper investigates into the cognitive foundations and processes of consciousness and their formal models. It is an intensive extension of an invited plenary talk at *the 2009 International Conference Towards the Science of Consciousness* (Wang, 2009g). In the remainder of this paper, Section 2 explores cognitive informatics foundations of consciousness and how it is generation from neural and physiological structures. Section 3 develops the abstract intelligence theory and mathematical models of consciousness with a computational intelligence treatment. Section 4 presents the cognitive process of consciousness by structural and behavioral models. The hierarchical reduction of consciousness between its mathematical, functional (process),

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