The Cognitive Process and Formal Models of Human Attentions

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ABSTRACT

Attention is a complex mental function of humans in order to capture and serve the basic senses of vision, hearing, touch, smell, and taste, as well as internal motivations and perceptions. This paper presents a formal model and a cognitive process for rigorously explaining human attentions. Cognitive foundations of attentions and their relationships with consciousness and other perception processes are explored. The closed loop of attentions is identified that encompasses event capture and behavior reaction. Events for attention are classified into the categories of external stimuli and internal motivations. Behaviors as corresponding responses of attentions encompass recurrent, temporary, and reflex actions. Mathematical models of attentions are created as a foundation for rigorously describing the cognitive process of attentions in denotational mathematics. A wide range of applications of the unified attention model are identified in cognitive informatics, cognitive computing, and computational intelligence toward the mimic and simulation of human attention and perception in cognitive computers, cognitive robotics, and cognitive systems.

Keywords: *Artificial Intelligence (AI), Brain Science, Cognitive Computing, Cognitive Informatics, Computational Intelligence, Consciousness, Denotational Mathematics, eBrain, Layered Reference Model of the Brain (LRMB), Natural Intelligence, Neuroinformatics, Real-Time Process Algebra (RTPA)*

1. INTRODUCTION

Attention is a hybrid conscious and subconscious mental process of the brain. It is a core feature of human intelligence that maintains a long chain of thinking threads and a long period of focus on highly complex cognitive processes. Human attentions as a form of perceptive action intelligence are far beyond those of any other advanced species. Rees and his colleagues viewed attention as a conscious selection characterized by a particular object, a train of thought, or a location in space (Rees et al., 1997). Robbins classified the functions of attention into the types of orienting

to sensory stimuli, selecting the contents of consciousness, and maintaining alertness (Robbins, 1997). Various perspectives on the nature of human attentions have been proposed such as the *filter* model (Broadbent, 1958), the *attenuator* model (Treisman, 1960), the *transparent transformation* model (Lachman et al., 1979), and the *pertinence* model (Norman & Shallice, 1986).

Definition 1: *Attention* is a perceptive process of the brain that focuses the mind or the perceptive engine on external stimuli, internal motivations, and/or threads of thought by selective concentration and proper responses.

Attention is a cognitive sign of consciousness. It is one of the top-level human action intelligence in order to carry out proper perception, thinking, and related actions. The driving power of human attentions is the perceptive engine embodied by the brain stem and cerebellum for sensory and consciousness, respectively (Wang, 2013a, 2013d). Attention is dominantly manipulated by the eyes, because they are the receptor of more than 70% of external stimuli and information to the brain (Coaen et al., 1994; Marieb, 1992; Sternberg, 1998). Attention is triggered by all five primary sensory receptors such as vision, hearing, smell, taste, and touch, as well as derived internal senses of position, time, and motion, at the sensation layer. Attention also interacts with consciousness and other perceptive processes in the brain (Kihlstrom, 1987; Wang, 2012f, 20012g; Wang et al., 2006).

Attention is a cognitive process at the perception layer according to the *Layered Reference Model of the Brain* (LRMB) as shown in Figure 1 (Wang et al., 2006). To be a counterpart of the *inference intelligence*, attention is one of the eight perception processes of the brain at the highest layer of human *action intelligence*, closely interacting with *consciousness* (Wang, 2012f), *motivations/emotions/attitudes* (Wang, 2007e), *imagination*, *sense of spatiality* (Wang, 2009c), and *sense of motion* (Wang, 2009c). Attention is supported by lower layer functions such as those at the sensation, action, and memory layers. It also intensively interacts with higher layer life functions and mental processes in the brain such as the meta-cognitive, inference, and complex cognitive processes that form the inference intelligence.

The LRMB model establishes a dynamic context of the brain as an extremely intricate real-time intelligence system where attention serves as the event capturer and response dispatcher. It is noteworthy in LRMB that most inherited life functions are subconscious or unconscious. However, most acquired life functions are conscious. Although we cannot intentionally control the subconscious and unconscious processes in the brain, we do autonomously apply them repetitively every second in any conscious processes.

This paper presents the cognitive foundations and processes of human attentions. In the remainder of this paper, the cognitive informatics and neurophysiologiocal foundations of attentions are explored in Section 2, which lead to a unified model of selective attentions. Section 3 creates the mathematical model of attentions that rigorously elaborates the nature of human attentions. Section 4 formally models and explains the cognitive process of mental attentions. As a result, the cognitive mechanisms of human attentions at the logical, abstract intelligence, cognitive informatics, brain informatics, and neurophysiological levels are systematically revealed.

2. THE COGNITIVE INFORMATICS FOUNDATIONS OF HUMAN ATTENTIONS

Attention is a mental perceptive engine that focuses on a certain event and related cognitive process among multiple external stimuli and internal motivations. Attention can be classified as

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