Neuroinformatics Models of Human Memory:

Mapping the Cognitive Functions of Memory onto Neurophysiological Structures of the Brain

Yingxu Wang, International Institute of Cognitive Informatics and Cognitive Computing (ICIC), University of Calgary, Calgary, AB, Canada

ABSTRACT

The human brain is a superbly marvelous and extremely complicated neurophysiological structure for generating natural intelligence that transforms cognitive information into colorful behaviors. The brain is the most complex and interesting objects in nature that requires rigorous scientific investigations by multidisciplinary methodologies and via transdisciplinary approaches where only low-level studies could not explain it. A fundamental problem and difficulty in contemporary brain science is the indistinguishable confusion of the cognitive mechanisms and neurophysiological structures of the kernel brain and its memories. This paper presents a set of formal neuroinformatics models of memory and a rigorous mapping between the cognitive functions of memory and their neurophysiological structures. The neurophysiological foundations of memory are rigorously described based on comprehensive cognitive models of memory. The cognitive architecture of human memory and its relationship to the intelligence power of the brain are logically analyzed. The cognitive roles of memory allocated in both cerebrum and cerebellum are revealed by mapping the functional models of memory onto corresponding neurophysiological structures of the brain. As a result, fundamental properties of memory and knowledge as well as their neurophysiological forms in the brain are systematically explained.

Keywords: *Abstract Intelligence, Brain Informatics, Cognitive Computers, Denotational Mathematics, Engineering Applications, Memory Theory, Natural Intelligence, Semantic Algebra, Visual Semantic Algebra*

1. INTRODUCTION

The brain is the most complex and interesting objects in nature that demands rigorous scientific investigations by multidisciplinary methodologies and via transdisciplinary approaches where only low-level studies could not explain it. A basic empirical assumption in brain science is that the mass of the brain plays an important role in the implementation of the natural intelligence

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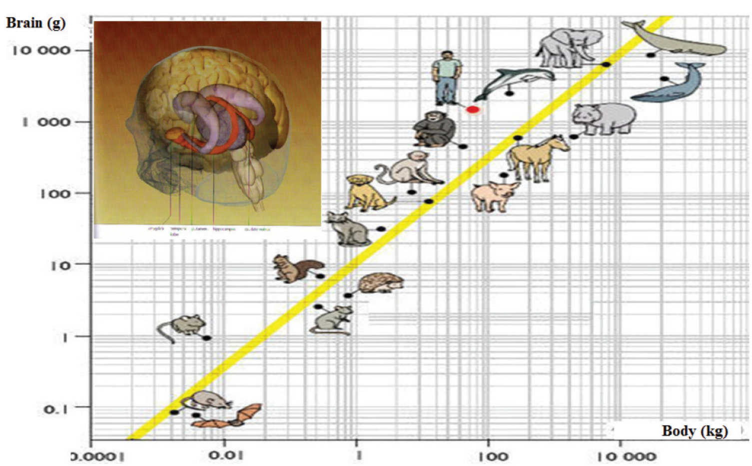
(Anderson, 1983; Marieb, 1992; Sternberg, 1998; Bower, 1998; Dayan & Abbott, 2001; Woolsey, 2008; Carter & Frith, 2009; Wilson & Keil, 2001; Wang, 2002a, 2003, 2012g, 2012i, 2012m) because all functions of the brain for information processing, memory, and the central nervous system require the support of certain physiological structures. The ratio between the mass of brains and the weight of the bodies across advanced species seem to be logarithmically linear as shown in Figure 1, which indicates an average *brain-body ratio* $r_a = 0.001$, approximately. However, the brain-body ratio of humans is outstandingly high, i.e., $r_h = 0.023$, which is 22.86 times higher than the average of other advanced species.

Therefore, it is curies to seek the impacts of the outstanding brain capacity of humans on their cognitive ability. How does natural intelligence be generated as a highly complex cognitive state in human mind on the basis of neurological and physiological structures? How may natural intelligence be explained across the neurological, physiological, cognitive, and abstract levels? How are natural and artificial intelligence converged on the basis of brain science, cognitive science, and cognitive informatics? These fundamental questions are systematically examined in cognitive informatics (Destexhe, 2006; Wang, 2002a, 2003, 2006, 2007b, 2007c, 2007d, 2008f, 2009a, 2009b, 2009d, 2009e, 2009i, 2010a, 2010b, 2011b, 2011d, 2012d, 2012e, 2012f, 2012g, 2012i, 2012j, 2012k, 2012*l*, 2012m, 2013a, 2013b, 2013c; Wang & Wang, 2006; Wang & Fariello, 2012; Wang et al., 2006, 2009, 2010a, 2010b, 2012l; Tian et al. 2011), abstract intelligence (Wang, 2009a, 2012i, 2012m, 2013b), and denotational mathematics (Wang, 2002b, 2007a, 2008a, 2008b, 2008c, 2008d, 2008e, 2008g, 2008i, 2009c, 2009f, 2010c, 2010d, 2011a, 2011c, 2012a, 2012b, 2012c, 2012h; Wang & Chiew, 2011), which lead to a series of interesting findings on the qualitative and quantitative advances of human brain and its rational mechanisms.

The memory organs in cerebrum and cerebellum is a crucial part of the brain, which possess over 60% of the mass of the brain and are the only physiological structures in the adult brain that may continually growing (Marieb, 1992; Pinel, 1997; Sternberg, 1998; Wilson & Keil, 2001; Wang, 2012i; Wang & Fariello, 2012). Memory is the foundation for maintaining a stable state of any animate system. It is also the foundation for any form of natural or machine intelligent systems (Wang, 2003; Wang & Wang, 2006). The term memory implies two semantic denotations in brain studies: a) The *memory organs* where cognitive information is retained; and b) The

Figure 1. The brain-body ratio across species



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