Chapter 9
The Hidden Markov Brains

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ABSTRACT

This chapter presents Hidden Markov models (HMM) of the brain on Magnetic Resonance Imaging (MRI) for the inference of white matter hyperintensities and brain age prediction to study the bidirectional vascular depression hypothesis in the elderly and neurodegenerative diseases, respectively. Rating and quantification of cerebral white matter hyperintensities on magnetic resonance imaging are important tasks in various clinical and scientific settings. The authors have proposed that prior knowledge about white matter hyperintensities can be accumulated and utilised to enable a reliable inference of the rating of a new white matter hyperintensity observation. The use of HMM for rating inference of white matter hyperintensities can be used as a computerized rating-assisting tool and can be very economical for diagnostic evaluation of brain tissue lesions. They have also applied HMM for MRI-based brain age prediction. Cortical thinning and intracortical gray matter volume losses are widely observed in normal ageing, while the decreasing rate of the volume loss in subjects with neurodegenerative diseases such as Alzheimer's disease is reported to be faster than the average speed. Therefore, neurodegenerative disease is considered as accelerated aging. Accurate detection of accelerated ageing of the brain is a relatively new direction of research in computational neuroscience, as it has the potential to offer positive clinical outcome through early intervention.

INTRODUCTION

Neurodegenerative and cardiovascular diseases and depression in ageing populations are important and long-standing areas of biomedical research. Over the past two decades, there have been many reports on systematic links of the heart with the brain as well as the heart with the mind (Coffey, Figiel, Djang, & Weiner, 1990; Sheline, et al., 2008). Most exciting findings and validations of life science hypotheses can be tremendously assisted with a variety of computer-based methods

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in image analysis, signal processing, and pattern recognition. The convergence of the divergence of neurology and psychiatry has given birth to modern neuroscience (Coffey, et al., 1990), where cognitive neuroscience, linguistics, and computational science play important roles for the exploration of mind and brain study.

To combine psychology with physiology, psychophysiology has been developed to address the physiological bases of psychological processes. This study also used to be known as cognitive neuroscience. For example, psychologists are interested in why depressive patients positively respond to certain pieces of music and physiologists may be interested in the input/output system of the amygdala. A psychophysiologist will attempt to link the two by trying to explain the favourable reception in terms of impulses coming in and out of the amygdala. Psychophysiology is different from physiological psychology in that psychophysiology looks at the way psychological activities produce physiological responses, while physiological psychology looks at the physiological mechanisms, which lead to psychological activity. More recently, psychophysiologists are interested in the central nervous system, exploring cortical brain potentials such as the many types of Event-Related Potentials (ERPs), brain waves, functional neuroimaging (fMRI), Positron Emission Tomography (PET), and so on. Psychophysiology is closely related to the field of neuroscience, which primarily concerns itself with relationships between psychological events and brain responses. Psychophysiology is also related to the medical discipline known as psychosomatics. Psychophysiology has found itself positioned at the intersection of psychological and medical science, and its popularity and importance have expanded commensurately with the realization of the inter-relatedness of mind and body.

It has recently been reported that social medicine scientists, psychiatrists, and psychologists have become interested in the study of the associations of depression, dementia, and vascular disease (Iverson, et al., 2005; Sheline, et al., 2008). This study tries to understand how social and economic conditions impact health and disease so that conditions resulting from which this understanding can lead to a healthier society can be fostered. Since the understanding of neuropharmacology and the identification of neurotransmitters, which have led to the emergence of biological psychiatry, psychiatric research focused on measuring neurotransmitter levels in the brain, spinal fluid, or urine and identifying receptor modifications associated with disease (Martin, 2002). Neurologic and psychiatric research have been more and more closely working together in tools, methodologies, and the areas of scientific discovery. The development of functional imaging techniques, including magnetic resonance imaging, positron emission tomography, and computerized tomography with rapid infusion are now used not only by neurologists and psychiatrists but also by psychologists and cognitive neuroscientists (Martin, 2002). It has been recently reported that developments using transcranial magnetic stimulation have provided effective ways to temporarily interrupt cognitive functions, such as visual spatial attention (Hilgetag, Theoret, & Pascual-Leone, 2001) as well as delivering other promising approaches besides Electroconvulsive Therapy (ECT) for the treatment of depression (George, et al., 1999).

There is little understanding about the relationship between the brain and mental processes and how precisely the brain gives rise to various mental processes (Kandel, 1998). Kandel (1998) pointed out that the great challenge for biology and psychiatry is to delineate that relationship in terms that are satisfying to both the biologist of the brain and the psychiatrist of the mind. As a result of advances, both psychiatry and neural science are in a new and better position for a novel integration that would allow the insights of the psychoanalytic perspective to inform the search for a deeper understanding of the biological basis of behaviour. With the advent of psychopharmacology, psychiatry has changed, and that change