

Preface

Dementia is a progressive neurodegenerative disease, of which Alzheimer's disease (AD) is the most frequent cause. AD is characterized by the progressive formation of insoluble amyloid plaques and vascular deposits of amyloid beta peptide in the brain. AD patients suffer from a loss of neurons and synapses in the cerebral cortex and certain sub-cortical regions. Numerous researchers in pathophysiology and molecular neurology have focused on the cause of AD in an effort to identify clinical markers, such as the beta-site amyloid precursor protein-cleaving enzyme 1, which can be used to diagnose AD. However, until recently, there were no medical tests capable of conclusively diagnosing AD pre-mortem. The mini-mental state examination (MMSE), a brief, 30-point questionnaire, as well as the clinical dementia rating (CDR), a five-point numeric scale, are the standard tests used to help the physician determine whether a person suffering from memory impairments has AD. Both of these tests include simple questions and problems in a number of areas, such as arithmetic, memory and orientation, used to quantify the severity of dementia symptoms. However, the sensitivity of the MMSE test is approximately 80%, and it has very limited use in screening for patients with mild cognitive impairment (MCI), a major risk factor for the development of AD.

The application of neuroimaging technology to the study of AD has been steadily increasing over the last two decades. To date, the majority of neuroimaging reports that have contributed to the understanding of the pathophysiology and clinical course of AD have utilized structural magnetic resonance imaging (MRI) and positron emission tomography (PET). In addition, functional MRI (fMRI) has been used as a research tool to study AD since 1999. The fMRI studies of AD have focused on two overlapping objectives: understanding the basic biological mechanisms and pathophysiology of AD and developing an effective diagnostic tool or clinical biomarker. The development of biomarkers via fMRI is anticipated to influence the clinical management of AD in three significant ways: differentiating healthy aging from AD, enhancing diagnostic specificity when evaluating a patient with dementia, and monitoring the biological progression of AD for the purposes of drug development and drug testing.

Recent fMRI studies have used spatial attention tasks to study the different neural substrates activated in adults with AD and in normal age-matched adults. These reports found that the most pronounced differences between the two groups were found in the superior parietal lobule (SPL), which was more highly activated in controls, and the frontal and occipitotemporal (OCT) areas, which showed greater activity in AD patients. Differentiating between default networks in AD and normal age-matched adults is another approach and typically uses independent component analysis. A third kind of study uses functional connectivity MRI and focuses on the identification of hubs within the human cerebral cortex, determining the stability of hubs across subject groups and task states and exploring whether the locations of hubs can be correlated with one component of AD pathology.

In the very early stages of AD, altered cognitive symptoms involve mild impairments in learning, memory, or planning. Several researchers use cognitive tasks, including memory tasks, visuospatial tasks, and language tasks, in order to identify differences in cognitive function between AD patients and normal controls. These studies have convincingly demonstrated that it is possible to use cognitive tasks to detect deficits in AD patients during a preclinical period spanning several years. For instance, some researchers have found high levels of pathological lesions in the primary visual areas and certain visual association areas within the occipito-parieto-temporal junction and posterior cingulate cortex in AD patients.

Language is succinctly defined as a “human system of communication that uses arbitrary signals, such as voice sounds, gestures, or written symbols”. This system is used to encode and decode information. In the literature on dementia, the presence or absence of language deficits has come to occupy a pivotal position with respect to certain nosological and nosographical issues. Simply using the correct language engenders trust. This is especially true of the language we use when talking about medical issues—particularly AD. Media reports on AD contribute significantly to the public’s awareness and knowledge of the condition. Increasing the general understanding of dementia makes seeking diagnosis or support easier for people with concerns about memory loss. The more that other people understand about their experience, the better the quality of life will be for people living with dementia. Language appears to be affected in the early stages of dementia, but the effect is often seen only in selected areas and with significant individual variability. It would appear that impairments in transcribing dictated information and in the pragmatic use of language can be detected early if sensitive tasks are employed. Performance transcribing dictations may indicate a partial lexical knowledge of written words, suggesting that some features of the words’ specification in the brain’s lexical stores are either absent or inaccessible as a result of brain degeneration.

New efforts have been made to find a preclinical marker for the early detection of AD using tactile discrimination procedures. In order to discriminate different objects by touch alone, humans need to store the spatial information from the first object in their working memory and then compare that spatial construction to the second object. This procedure activates a widely distributed cerebral network, which includes areas for the initial processing of skin indentations, the computation and elaborate reconstruction of shapes and the processing of tactile working memory. The abnormal processing of somatosensory information in AD patients is thought to contribute to a functional decline in tactile shape discrimination compared to normal controls.

Dyslexia is a learning disorder that manifests itself as a difficulty with reading, decoding, comprehension, and/or fluency. It is separate and distinct from reading difficulties resulting from other causes, such as non-neurological deficiencies in vision or hearing, or from poor or inadequate reading instruction. It is estimated that dyslexia affects between 5-17% of the U.S. population. Dyslexia is thought to be the result of a neurological defect/difference, and while it is not an intellectual disability, it is variously considered to be a learning disability, a language disability and a reading disability, among other categories. Persons with dyslexia may have an Intelligence Quotient (IQ) that ranges anywhere from 70 to well above average. Dyslexia is a condition that is neurological in origin and is thus not attributed to factors such as socio-economic background, a lack of motivation to learn, or IQ level. Research using brain-imaging techniques indicates that physiological differences in the brains of dyslexics underlie differences in cognitive functioning and development. At the cognitive level, these deficits may occur in visual processing, linguistic processes (such as phonological representation), and memory.

Another group of neurological deficits stem from motor neuron disease (MND). MNDs are a group of neurological disorders that selectively affect motor neurons, the cells that control voluntary muscle activity including speaking, walking, breathing, swallowing, and general movement of the body.

Rehabilitation robotics is a special branch of robotics that focuses on machines that can be used to help people recover from severe physical trauma. Rehabilitation robotics has only recently begun to make serious inroads in the world of physical therapy, but in many cases, the results are miraculous.

There is increasing interest in using robotic devices to provide rehabilitation therapy following neurological injuries, such as stroke and spinal cord injury. The general paradigm uses a robotic device to physically interact with the participant's limbs during movement training, although there are also paradigms in which the robot "coaches" the participant without making physical contact.

Biomechatronics is an applied interdisciplinary science that aims to integrate mechanical elements, electronics and parts of biological organisms. It also encompasses the fields of robotics and neuroscience. Three main areas are emphasized in current Biomechatronics research.

Following the original demonstration that electrical activity generated by ensembles of cortical neurons can be employed directly to control a robotic manipulator, research on brain-machine interfaces (BMIs) has experienced impressive growth. BMIs provide a digital channel between the brain and the physical world. Electrophysiological measurements of brain activity, such as electromyography (EMG), electroencephalograms (EEGs) and electrooculograms (EOGs) can provide a non-muscular channel through which external devices can be controlled. Previous research recently presented a survey on EEG based brain-machine interfaces (BMIs) and the feasibility of a brain interface to control wheel chairs.

Recent advances in the analysis of brain signals, training patients to control these signals, and improved computing capabilities have enabled people with severe motor disabilities to use their neural signals for both communication and control of objects in their environment, thereby bypassing their impaired neuromuscular system. Non-invasive, EEG-based brain-computer interface (BCI) technologies can be used to control a computer cursor or a limb orthosis, for word processing and accessing the Internet, as well as other functions, such as environmental control or entertainment. With the advent of non-invasive electrodes, EEG research has been directed towards the development of BMIs to replace damaged motor nerves.

Clearly, these developments hold promise for the restoration or replacement of limb mobility in paralyzed subjects. In the future, however, several hurdles will have to be passed. These include designing a fully implantable biocompatible recording device, further developing real-time computational algorithms, introducing a method for providing the brain with sensory feedback from the actuators, and designing and building artificial prostheses that can be controlled directly by brain-derived signals

Dementia is a serious loss of cognitive ability in a previously unimpaired person beyond what might be expected from normal aging. It may be static, as in the case of a unique global brain injury, or progressive, resulting in long-term decline due to damage or disease in the body. Although dementia is far more common in the geriatric population, it can occur in any stage of adulthood. Similar sets of symptoms due to organic brain syndromes or dysfunction are given different names when they occur before adulthood. Until the end of the nineteenth century, dementia was a much broader clinical concept.

The diseases that can cause dementia include Alzheimer's disease, vascular dementia, Lewy body dementia, fronto-temporal dementia, Huntington's disease, and Creutzfeldt-Jakob disease. Doctors have identified other conditions that can cause dementia or dementia-like symptoms, including reactions to medications, metabolic problems and endocrine abnormalities, nutritional deficiencies, infections, poisoning, brain tumors, anoxia or hypoxia, and heart and lung problems.

While there is no cure for dementia, advances have been made toward developing medications that can slow down the process. Cholinesterase inhibitors are often used early in the course of the disease. Cognitive and behavioral interventions may also be appropriate. Educating and providing emotional support to the caregiver are also important. There is some evidence that the regular, moderate consumption of alcohol and a Mediterranean diet may reduce the risk of developing dementia. In addition, a recent study has shown a link between high blood pressure and developing dementia. The study, published in the *Lancet Neurology Journal* in July 2008, found that medications that lower blood pressure reduced dementia by 13%.

Neurological rehabilitation is often used to reduce physical and cognitive impairments and related disabilities. It has also been shown to increase independence, so patients can participate in daily self-care and other activities to improve their health-related quality of life (QOL). Learning skills after a stroke, a traumatic brain or spinal cord injury or other diseases target the neural networks for movement, sensation, perception, memory, planning, motivation, reward, language, and other aspects of cognition that remain undamaged to compensate for those that were lost.

The rehabilitation of sensory and cognitive functions typically involves retraining neural pathways or training new neural pathways to regain or improve the neurocognitive functioning that has been diminished by disease or traumatic injury.

Speech therapy, occupational therapy and other methods that “exercise” specific brain functions are used. For example, eye-hand coordination exercises may rehabilitate certain motor deficits, while well-structured planning and organizing exercises might help rehabilitate certain frontal lobe “executive functions” following a traumatic blow to the head.

Jinglong Wu
Okayama University, Japan