CHAPTER 1- INTRODUCTION

Most aspects of human life, from genetic expression to brain structure and function, to cognitive processes to overt behavior are the result of development over time. Childhood is one of the most challenging stages of human life. It is a stage characterized by constant growth and development- physically and psychologically.

1.1 THE BRAIN AND DEVELOPMENT: The brain is a complex entity and has to be studied from various perspectives. The development of the cerebral cortex with its distinct cellular, molecular and functional characteristics is central to the understanding of human cognition. (Rakic,1995). A major event in the pre-natal development of the brain is the production of neurons and migration of cells from the position of their origin, to their final position in the cortex. Studies of cell migration enable analysis of developmental mechanisms of cell motility and identification of the molecules that help neurons trans-locate their bodies over long distances and find their proper “addresses” in the brain.

Dynamic interpretation of cortico-genesis is offered by advanced methods such as electron microscopy, axonal tracing, immuno-cytochemistry and in situ hybridization (Levitt, 1995). Challenging the normal course of development has also been attempted through experiments such as prenatal manipulation of cortical development, homotypic and heterotypic transplantation or creation of chimeric and transgenic animals. These studies have collectively demonstrated that initial development of the cerebral cortex is specified intrinsically by instructions within cell lineages, while the later phases are much more dependant on neuronal activity(Rakic, 1995)

Structure-function relationships in the cerebral cortex have their foundation in the initial formation of specific areas and circuits during development. Cell
proliferation, phenotype differentiation, cell migration and circuit formation are the events that underlie cortical formation (Levitt, 1995). Novel experimental approaches such as retrovirus lineage markers, cell and tissue transplantation and tissue culture approaches are revealing new concepts of the **molecular and cellular basis** for each of these ontogenetic events. The neonate cortex is neither localized nor specialized at birth, thereby allowing interaction with the environment, to play a role in gene expression and in the ultimate cognitive phenotype (Goldman-Rakic, 1987, Karmilof-Smith, 1998, Majdan & Schatz, 2006).

**Picture 1 shows the stages of growth of the brain from the first to the ninth month after birth.**

Human behavior is complex and rarely dependant on a single cognitive process. Perception, emotion, thinking and motor functions are not nearly as separate as previously thought (Munakata, Casey and Diamond, 2004). The developing brain has cortical regions that are **highly interconnected**. Higher order functions are sub served by **widely distributed** and integrated brain systems or networks.
(Goldman-Rakic, 1998). These networks ensure that functions are under **multiple controls** and hence are fundamentally interrelated (Diamond, 2000).

Cognitive development (pre-frontal cortex) has generally been viewed as the last aspect of development to fully mature. Motor development (cerebellum) also can be similarly protracted; it was not earlier thought that the pre-frontal cortex and the neo-cerebellum would participate in similar functions (Diamond, 2000). Activation in these regions is strikingly correlated and closely coupled. They participate as **critical parts of a neural circuit**, when the cognitive task is new, difficult, require quick response and conditions of the task change. Efficiency increases after repetitive practice of specific cognitive operations. Practice produces adaptations in underlying neuro-anatomical networks linked to these processes. (Kerns, Eso, Thomson, 1999).

**Picture 2 showing the parts of the neuron**

1.2 **NEURONS AND NETWORKS**: The individuality of a single neuron is primarily determined, not only by their place in the neuron network, but also by their intrinsic properties (Arshavsky, 2001). Individual neurons can play an important, if not decisive role in performing cognitive functions. Receptive **language** is primarily a function of the temporal cortex, but studies with deaf
individuals have shown that while meaningful sign language activated the temporal area, meaningless actions can activate the visual cortex in the same individuals (Bellugi, Poizner & Klima, 1989, Poizner, Bellugi & Klima 1990, Hickok, Bellugi & Klima, 1998). Face selectivity is an inherent property of a group of neurons in the temporal cortex, while prosapagnosia or facial agnosia is attributed to damage in the visual association cortex. (McNeil & Warrington, 1993; Farah, 1996; Duchaine, 2000). Using a combination of genetic and behavior studies Grigorenko, Wood, Meyer, Hart, Speed, Shuster & Paulis (1997) concluded that loci on chromosomes 6 and 15 (which are correlated with reading disability), contribute to distinct phenotypes of the disability. Deficits in phonological awareness are linked to loci on chromosome 6, while loci on chromosome 15, are linked to deficits in word recognition, implying that different components of reading are possibly linked to separate genes. Proteins coded by these genes are, in some way, necessary for processing, oral reproduction, and comprehension of written text (Pennington, 1999, Plomin & Crabbe, 2000). Mutations of these genes lead to reading disability that cannot be compensated by the activity of other neurons or plasticity of inter-neural connections. Therefore, cognitive functions appear to be realized, not only at the network level, but also at the intra-cellular, possibly molecular level.

**Picture 3 shows the stages of transmission across the neuron**
Intercellular connections are used for patterning and synchronization of transmission of detailed information, concerning molecular processes occurring within neurons. This “binding hypothesis” (Crick & Koch, 1990; Tononi & Edelman, 2000; Engel, Fries, Konig, Brecht & Singer 1999) postulates that synchronization on a millisecond scale, of widely distributed sets of cerebral neurons, may form temporary assemblies that underlie different cognitive acts. Supporting evidence for synchronization has been obtained in electroencephalographic and magneto-encephalographic studies on humans (Damasio, Tranel & Damasio, 1990; Rodriguez, George, Lachaux, Martinerie, Renault, & Valera, 1999, Srinivasan, Russel, Edelman & Tononi, 1999). Circadian rhythm, on the other hand, is determined, to a large extent, by intracellular molecular processes within specialized neurons, which operate in a cell-autonomous manner; while the synaptic interactions between neurons determine their synchronizing activity (King & Takahashi, 2000; Young, 2000).

Thus, many specific cognitive functions are carried out by groups of highly specialized neurons, whose role is genetically pre-determined and whose activity cannot be substituted by other neurons. The main role of neural networks and intercellular interactions is therefore, to form dynamic ensembles of neurons involved in performing a specific cognitive function.

1.3 TRAJECTORY OF COGNITIVE DEVELOPMENT: In one of the first attempts to study the developmental trajectories of cognitive functions using neuro-imaging techniques, Waber, DeMoor, Forbes, Almli, Botteron, Gabriel et al (2007) used the fMRI to obtain cross sectional data on a group of healthy children aged 6-16 years in various functions. Age-related trajectories on most measures of cognitive performance showed dramatic improvement in proficiency between 6 and 10 years, and leveling off during early adolescence (10 to 12 years). Tasks that assessed basic information processing such as coding, digit span, and spatial span increased linearly throughout age. Some showed a flattening, followed by a mid-adolescence spurt. Verbal learning reversed direction with performance declining in later adolescence. Thus, developmental changes take place in chronologically and qualitatively different ways in various regions of the brain.
Differential rates of maturity and control of functions by wide networks are two important factors that could provide clues in understanding why some children are different from others, or why problems seen earlier in childhood, seem more manageable, or even disappear over time. These could also be challenges in planning interventions for children, as the effectiveness of the technique may be a product of the technique itself as well as the developmental readiness of the child. Thus, the increasing knowledge of the child’s brain and its functioning provides newer information that could help us understand not just the successes, but also the failure in intervention techniques for children.

1.4 WHO IS A CHILD AT RISK? Childhood is also a stage when mental problems are the most difficult to diagnose. One of the main reasons perhaps, is that, “…most of the defining clinical signs of psychiatric disorders also occur in normally developing children” (Klein, 2011). Therefore, the boundaries that define deviance and psychopathology remain controversial. This is even more so, in problems such as learning difficulties, where multiple factors can contribute to success or failure in school related skills such as reading, writing and arithmetic. Apart from the home, school is the significant learning environment for the child. An index of the child’s learning is performance in the school assessments, usually grades, or marks. It is expected that, with adequate teaching methods and practice,
the child would attain mastery over the concepts required at different classes. This is more so in lower classes where teaching is activity based and the verbal load in exams is relatively less.

The results of an unpublished analysis conducted (by the researcher) in 2 schools near the hospital where the study was carried out, indicated that a majority of children in classes 3, 4, and 5 are able to score more than 70% marks (or equivalent grades) in the major school examinations. However, about 20% of the students score between 40-60%. This trend was seen consistently, across the schools, as well within the same school over 2 years, indicating that about 70% of children are able to cope well with the academic load in the early school years. The question therefore is why are 20% of children obtaining only pass grades or scoring below most of their peers? Will these children be able to cope with the increased demands in the curriculum, as they advance through school? Logically, it does not appear possible, because mastery over a particular set of concepts would pave the way for better ability to cope with the next level of these concepts, which are usually faced in the next grade. However, some children do catch up later while others may not.

Can this group of children who are average in scholastic performance be considered learning disabled or “at risk” for learning disability? Preliminary research (Leach, Scarborough & Rescorla, 2003) seems to suggest that learning difficulties can be late emerging, and not late identified i.e. children can be considered adequate or average in lower classes, but can develop difficulties in learning, later on. A different approach was used by the Boston group of researchers (Morgan, Singer-Harris, Bernstein & Waber, 2000; Singer-Harris, Forbes, Weiler, Bellinger & Waber, 2001) who studied children who are apparently adequate in scholastic performance, but were referred by teachers for learning difficulties. This group had a neuropsychological profile that was similar to children with identified dyslexia, with significant deficits in information processing. The authors conclude that learning difficulties could be viewed as a continuum, with dyslexia representing the severe end and moderate and mild levels of the learning difficulties being present further away. Adequate or average
scholastic performance in lower classes can therefore be taken as a potential risk factor for future scholastic difficulties.

A diagnosis of mild or moderate learning difficulties is often more difficult than that of severe difficulty, especially in young children who are in the process of rapid and varied development. Ideally, all students should be screened early for potential problems in academics and behavioural domains. One promising approach to identification is to use the school curriculum itself (Vaughn & Fuchs, 2003). Curriculum-based measurement may be particularly relevant for ecological validity. It represents an assessment method that can provide the multiple sources of documentation required for modelling academic growth, distinguishing between ineffective general education environments and acceptable student learning, and evaluating instruction effectiveness (Fuchs, Fuchs, Prentice, Burch & Paulsen, 2002).

1.5 THE RESPONSIVENESS TO INTERVENTION model, (Heller, Holtzman & Messick, 1982; Fuchs, 1995; Fuchs & Fuchs, 1998; Vellutino, Scanlon, Sipay, Small, Pratt, Chen et al, 1996) offers promise in this direction. This model identifies children as learning disabled only when their response to validated intervention is dramatically inferior to that of their peers. The inference is that children, who respond poorly to generally effective interventions, have a difficulty that requires specialised help (Fuchs, Fuchs& Hollenbeck, 2007).

Children with mild or moderate difficulties at school also need help. The model for identification needs to move away from students with deficits to students at risk for deficits. The “wait to fail” approach needs to shift to early identification and early intervention. Early identification reduces the likelihood that students with undetected learning problems will slip through the system. Screening at a younger age might be less precise, over-identify problems and produce more false positives. However, this might be a better alternative than withholding intervention until a later age, when the child may have a significant difficulty in coping with the academic load.
This procedure therefore has the potential to benefit several students. The bias inherent in the teacher-based referral process is reduced. The current bias in under identifying girls with learning difficulties will also be reduced. Implementing this model would help move away from a deficit model to a risk model for both identifying and intervening with students with learning disability. This would also benefit students with learning difficulties, without learning disability.

This model offers immense scope for a multi-lingual country such as India, where children enter the formal schooling process by the age of 3, where the language of instruction is usually not the one spoken at home, and where there is little uniformity in educational system across the country. Against this background, the possibility of child failing to cope with the academic demand is high. Primary and secondary prevention approaches, therefore have to be seriously considered, especially in the lower classes.

This research study aims to incorporate lessons from both the conceptual models of learning as well as the applied aspects. It attempts to understand the profile of children with average scholastic performance in the lower classes, on the premise that average performance at that stage is a risk factor for future underachievement or scholastic difficulties in the higher classes. Based on the available literature, it presumes that one of the reasons for the average level is inadequacy in core neuropsychological functions such as speed of processing, attention and working memory. Then, it attempts to check the effectiveness of a computer-based intervention (targeting these functions) on the academic performance of these children. Response to such intervention would help understand whether the child continues to be at risk, or is better equipped to cope with the academic demands of the particular class.

In India, there is a dearth of studies that have incorporated technology in intervention. Hence, this is also an exploratory attempt that tries to assess the feasibility of this method of intervention in children at risk for future learning problems.