

**COMPARING THE EFFICACY OF PHONOLOGICAL  
AWARENESS INTERVENTION WITH  
NEUROPSYCHOLOGICAL INTERVENTION IN  
CHILDREN WITH SPECIFIC READING DISORDER**

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The material presented in this thesis is the original work of the candidate, except as acknowledged in the text, and has not been previously submitted, either in part or in whole, for a degree at this or any other university.

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## **ABSTRACT**

Phonological awareness is known to be associated with reading disorder. Intervention for specific reading disorder that focuses on training to improve phonological processing abilities has been found an effective means of addressing reading difficulties experienced by children. However, little is known as to what happens to other neurocognitive abilities associated with the process of reading but that are not causally linked to it. Some of these cognitions include attention, executive functions and verbal and visual memory. A series of three studies explored the relation between neuropsychological skills and phonological abilities in children with specific reading disorder.

The first step in the studies involved establishing deficits in associated cognitive abilities in children with specific reading disorder. Children attending the Literacy Clinic, Department of Communication Disorders, University of Canterbury, Christchurch, New Zealand, are screened for the presence of specific reading disorder. They are routinely assessed on reading and phonological processing measures before an intervention programme is initiated. Four such children who were assessed and identified as having specific reading disorder without speech language difficulties were chosen for the study.

These children, who ranged in age from 7 to 15 years, referred to as the RD group, were assessed during the week before the onset of the intervention for the neuropsychological functions of attention, executive functions, verbal and visual learning, and memory. After the assessment (termed pre-intervention assessment), they were provided with phonological processing intervention. The intervention programme was carried out by trained speech-language therapists and lasted for 10 weeks. Two sessions a week were conducted, giving a total of 20 sessions.

The week after completion of the intervention, the children were assessed once again on the same neuropsychological, reading and phonological awareness tests used before the intervention (termed post-intervention assessment). The results of the pre-intervention assessment were compared with the assessment of a group of typically developing group of children without reading disorder ( $N = 4$ ; age range 8 to 10 years; referred to as the NRD group).

Results indicated that, at pre-intervention assessment, the specific reading disorder (RD) group had deficits in verbal fluency and inhibitory control whereas the typically developing (NRD) group did not. The RD group also differed significantly from the NRD group in reading accuracy and comprehension. After the intervention, the RD group was assessed on reading, phonological processing, and neuropsychological tests. The group showed an improvement in reading accuracy and phonological processing. Of all the neuropsychological functions, only set shifting and visuo-spatial working memory scores showed a significant change in response to intervention. Deficits in executive functions and reading comprehension difficulties persisted.

It was hypothesised that the RD group improved in reading accuracy in response to the phonological awareness intervention. However, the persistent reading comprehension difficulties were hypothesised as attributable to the presence of the executive function deficits noticed in the RD group.

The exploratory study helped identify the presence of neuropsychological deficits in children with specific reading disorder in addition to their reading and phonological deficits. The study also established that phonological awareness intervention brought about a change in some neuropsychological function while other deficits persisted.

The phonological awareness intervention used in the first study was developed for children in New Zealand. The second study hypothesised that, if effective, this intervention would help address reading deficits found in other populations. Children from a culture outside New Zealand accordingly the same intervention as the New Zealand children received in the first study.

Children in Bangalore, India, 10 to 12 year of age and under-performing in their class, were screened for the presence of specific reading disorder. From this screening, 20 children with specific reading disorder (the RD group), with average to above average intelligence and without co-morbid psychiatric conditions were chosen to participate. Twenty children were randomly allotted to one of two treatment conditions. The first group of 10 children (the PA group) received phonological awareness intervention. The second group of 10 children (the NP group) received neuropsychological intervention. All 20 children were assessed on reading, phonological awareness tests and neuropsychological tests before and after intervention. Phonological measures included, Queensland University Inventory of Literacy (QUIL, ) Sthal and Murray, Phonological awareness probes of tracking speech sounds and non-word reading tests. Neuropsychological measures included Controlled Word Association test (COWA), Digit Span, Spatial Span, Stroop Colour-Word Test Colour trails (A & B), Ray Auditory verbal learning test, Rey Osterriech Complex figure test and block design.

The scores from the pre-intervention assessment were compared to the assessment data for 20 typically developing, non-reading-disabled children (referred to as the control group). The control group was assessed once on neuropsychological tests and reading and phonological awareness measures (QUIL only).

The results indicated that the 20 children with reading disorder (the RD group) differed significantly from the control group on reading abilities. In addition, the two groups differed significantly on neuropsychological measures of attention (Colour Trail, Form A), set-shifting (Colour Trail, Form B), word reading and interference control (Stroop Colour-Word Test) and phonological awareness measures of non-word reading, syllable identification, visual rhyme, spoonerism, phoneme detection and phoneme deletion.

After intervention, the RD group was again assessed on reading, phonological awareness and neuropsychological measures. Both the intervention groups (PA and NP) showed improvements on reading. Both groups also made significant gains on neuropsychological measures and phonological awareness measures.

The PA group showed significant changes in verbal fluency, visual scanning and attention (Colour Trails, Form A), word reading (Stroop Colour-Word Test, verbal memory (Auditory Verbal Learning Test), immediate visual memory (Complex Figure Test) and visuo-construction abilities (Block Design Test).

Phonological measures that showed significant increase in response to intervention in this group included non-word reading, phoneme detection, phoneme segmentation, phoneme deletion and tracking of syllable sound changes via use of coloured blocks and letter tiles. The NP group showed significant change in neuropsychological functions such as verbal fluency, word reading and interference control (Stroop Colour-Word Test), verbal learning (Auditory Verbal Learning Test), immediate visual memory (Complex Figure Test) and visuo-construction ability (Block Design Test). The NP group also improved significantly on phonological awareness measures such as syllable



identification, spoken and visual rhyme, spoonerism, phoneme detection, phoneme deletion and tracking of syllable sound changes via use of coloured blocks.

This second study established that the two interventions helped improve reading abilities equally. However, the interventions differentially affected neuropsychological and phonological awareness functioning in the participants.

The third study explored the changes seen in the second study's two treatment groups (Group PA and Group NP) three months after the conclusion of the intervention programme. During the three-month period between the post-intervention assessment and the follow-up assessment, all 20 children attended regular school. They received no special help or input for their reading and spelling difficulties during this period. The follow-up assessment consisted of the same tests of reading and neuropsychological measures used at the pre- and post-intervention assessments.

The results showed that the groups had maintained the gains evident at the time of the post-intervention assessment on reading measures. The PA group's performance on the neuropsychological measures and phonological measures showed significant changes in digit span and interference control. In addition, a significant increase from the pre-intervention measures, not observed at the post-treatment assessment, was observed for set-shifting, verbal learning and memory and non-word reading. Visuo-spatial working memory showed a trend towards significance for the NP group on the follow-up assessment. Most other neuropsychological functions did not differ significantly from those evident at the time of the post-intervention assessment.

The NP group, like the PA group, showed a significant increase between pre-assessment and follow-up assessment on non-word reading, visual scanning, verbal

learning and visual perception. The increase noticed in these measures at the time of the post-treatment assessment, however, was not significant.

Comparisons between the PA and NP group at follow-up revealed that the PA group's performance was significantly better than the NP group's on digit backward and interference control, while the NP group performance was significantly better than the PA group's on verbal fluency. The two groups were comparable on all other neuropsychological, phonological awareness and reading measures.

The improvements noticed in both groups immediately after the intervention and then three months after intervention were hypothesised to have occurred because the interventions addressed reading along with other cognitive abilities (e.g., executive functions, attention, verbal learning and memory, visual learning and memory) addressed in the study. The improvements noticed in both groups after three months after intervention was hypothesised to be the outcome of improvements in the neuropsychological functions.

The series of three studies conducted as part of this research work has helped identify neuropsychological deficits in children with reading disorder that persisted after phonological awareness intervention. The provision of two different interventions to children with reading difficulties showed that these had positive outcomes not only for reading and phonological awareness but also for neuropsychological functioning.

The most important conclusion drawn from the findings of the three studies that form this doctoral research is that intervention for reading disorder is most likely to be effective when it addresses the reading and other associated cognitive skills that underlie the reading process. The two interventions used in the study had a similar effect on

reading. Both helped the participating children improve their reading scores and both helped maintain those improvements over time. It is hypothesised that the improvement observed was probably sustained over time because both interventions could have addressed the associated deficits (in addition to reading difficulties) known to occur in children with reading disorder. The efficacy of the phonological awareness intervention documented in the studies is strengthened by the finding that it was effective in treating reading disorders in children from different cultural and educational settings (New Zealand and India).

### **Publication arising out of the thesis**

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## **CHAPTER I: INTRODUCTION**

### **1.1 OVERVIEW**

Reading is a complex act that involves several processes occurring simultaneously and smoothly (Price, 2000). Unlike spoken language, acquisition of which is innate, reading has to be taught. Through instruction and adequate exposure, individuals become proficient in reading (Shaywitz, 2003). Research indicates that beginning readers and skilled readers employ different strategies to read and comprehend text. Beginning readers use an effortful process involving frequent decoding of individual words in order to access a word's meaning. Skilled readers can access a word's meaning more quickly because prior successful decoding experiences allow them to visually recognise a word based on both phonological and orthographic information. Reading at this stage becomes "automatic"; able readers do not need to break a word into its individual sounds in order to read it (Frackowiak et al., 2004; Geschwind & Galaburda, 1985; Habib, 2000). As the reader gains proficiency, speed and fluency of reading develop, allowing the reader to focus, with relative ease, on strategies to derive meaning from the text

Reading does not develop uniformly in all individuals. Some individuals take longer to acquire fluency in reading; others struggle to gain proficiency in early decoding ability. Persistent difficulties in reading interfere with children's ability to profit from classroom instruction and to gain knowledge through written text.

A persistent difficulty in reading words is referred to as reading disorder or reading disability. The research literature refers to two broad kinds of reading difficulty: (i)



acquired reading disorder; and (ii) developmental reading disorder. Acquired reading disorder refers to the inability of an individual to read words following an insult, injury or lesion to the brain. This form of reading difficulty is more likely to be described in individuals who have acquired skilled reading ability before the insult or injury and who subsequently experience difficulty reading.

Developmental reading disorder refers to an inability of the individual to acquire efficient reading ability despite having normal intelligence and adequate exposure to reading instruction, and to an occurrence that is not caused by any known sensory neurological dysfunction or brain damage. Developmental reading disorder occurs in childhood during the developmental years in the absence of perceptual, intellectual and behavioural disorders. It is also referred to as specific reading disorder because it specifically affects reading in children who otherwise seem to be developing typically.

Although the disorder is often described in children, it is also described in adults (Frackowiak et al., 2004; Shaywitz & Shaywitz, 2005). The reading difficulties experienced by these adults have their origins in childhood and are thus referred to as developmental reading disorder. The accounts of the studies undertaken for this thesis use the term specific reading disorder to refer to children or adults who have a developmental reading disorder.

Specific reading disorder affects about 2.5–5% of school-age children (Frackowiak et al., 2004; Shaywitz & Shaywitz, 2005). The prevalence rates across different population groups is influenced by several factors, such as the nature of the language in which the children read and write, the socioeconomic status of the child and his or her

family, the intelligence of the child, the education system within which the child is educated, and the genetic make-up of the family.

Our understanding of specific reading disorder derives from studies seeking to identify the factors that contribute to the normal development of reading in children and to determine how fluent/skilled readers differ from disabled readers (Habib, 2000; Leonard, Eckert, Given, Virginin, & Eden, 2006). Specific reading disorder initially was described predominantly in English-speaking countries. More recently, however, studies have explored the presence of the disorder in non-English speaking countries, and a greater interest in understanding reading disorder in bilingual and multilingual individuals is developing (Karanth, 2008). Reading fluency depends upon the skill of the reader to decode words into sounds. In transparent languages (i.e., languages that have a consistent grapheme to phoneme correspondence), word decoding is easier than it is in languages that have less consistent grapheme to phoneme correspondence.

The correlation between language and the development of reading is well established and further confirmed by findings that specific language impairments and reading difficulties are known to co-occur (Snowling, Bishop, & Stothard, 2000). Despite significant advancements in our understanding of the relationship between spoken and written language disorders in the English language, there is still a critical need to understand the influence of spoken language on reading disorder in children who are bilingual and/or multilingual and of children from different educational and cultural contexts.

The studies conducted for this thesis examined aspects of language and cognitive development in children in India who have specific reading disorder and are multilingual.

A pilot study of different interventions for monolingual English-speaking children in New Zealand was followed by an investigation of the effectiveness of two different interventions designed to enhance reading development in children in India.

The following review of the literature describes specific reading disorder in detail, including its causes and characteristics. It also documents literature offering theories to explain the disorder. Interventions designed to remediate the effects of the disorder are also examined.

## **1.2 SPECIFIC READING DISORDER: DEFINITION**

The term specific reading disorder is typically used to refer to difficulties experienced by individuals learning to read when there is a discrepancy between reading ability and intelligence despite adequate reading instruction. Critchley (1968) defined reading disorder as “a disorder manifest by difficulty in learning to read despite conventional instruction, adequate intelligence and sociocultural opportunities. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin” (p. 66). The first part of the definition highlights the relevance of adequate intelligence and opportunities to learn to read. The second provides some answer to the question of what causes the disorder by suggesting that constitutional factors are responsible. Research has since focused on what constitutional factors are responsible and how one can go about addressing these.

The term “dyslexia” is often used interchangeably with the terms “specific reading disorder” or “reading disorder”. The term dyslexia replaced the term developmental alexia in the 1960s. Dyslexia is used to describe a reading disability that includes speech and language deficits and right–left confusion. Dyslexia has traditionally

been defined via exclusionary criteria—that is, a severe reading difficulty in the absence of cognitive, sensory, neurological, and/or environmental factors (Velluntino, 1979)—but more recent definitions of dyslexia describe the symptoms of the disorder; some definitions include causal factors

According to a relatively recent definition from the British Dyslexia Association, Dyslexia is a specific learning difficulty which mainly affects the development of literacy and language related skills. It is likely to be present at birth and to be lifelong in its effects. It is characterised by difficulties with phonological processing, rapid naming, working memory, processing speed, and the automatic development of skills that may not match up to an individual's other cognitive abilities. It tends to be resistant to conventional teaching methods, but its effects can be mitigated by appropriately specific intervention, including the application of information technology and supportive counselling. (British Dyslexia Association, 2006, p. 11)

In this thesis, the term dyslexia is used when reference is made to studies that have adopted this term. Where this is not the case, the term specific reading disorder is used.

Specific reading disorder results in a difficulty in acquiring word-reading skills. It affects a significant proportion of school-age children and is a serious contributor to academic failure (Simos et al., 2002). It can persist throughout one's life and reading delay is just one of its manifestations (Ramus et al., 2003). Children with reading disorder who are undiagnosed or untreated are at high risk of academic underachievement, non-completion of high school or college, social-emotional problems associated with chronic school failure, and under-employment as adults (Aylward et al., 2003).

Awareness of these risks has led, in the past few years, to reading disorder attracting considerable interest from researchers in different scientific areas. Public

awareness that this condition has a neurological basis gave rise to the hope of rational and effective therapy, which stimulated research in different areas, such as neurophysiology, neuropathology, linguistics and the educational sciences. Today, specific reading disorder is a fertile ground for trans-disciplinary studies and a model for elucidating biological, educational and sociocultural factors of brain-cognition interactions and development. Also of relevance is the recent explosion of brain-imaging methods, which has provided a unique experimental setting for studying the brain mechanisms of reading in general and the reading abilities of impaired individuals in particular (Habib, 2000).

### **1.3 HISTORY OF SPECIFIC READING DISORDER**

The notion that specific reading disorder may have a neurological origin was independently considered by Scottish ophthalmologist James Hinshelwood and the British physician Pringle Morgan. Both men emphasised the similarity of certain symptoms in reading-disabled children or teenagers with the neurological syndrome of “visual word blindness” (Habib, 2000). As was first reported by the French neurologist Jules Dejerine, damage to the left inferior parieto-occipital region (in adults) results in a specific, more or less severe, impairment in reading and writing, suggesting that the left angular gyrus may play a role in the processing of optic images of letters. These early authors reasoned that impaired reading and writing in their young patients could be due to defective development of the same parietal region damaged in adult alexic patients.

Another line of neurological speculation followed the initial observations that children described as having dyslexia have poor or inadequate brain lateralisation, especially for language. One idea proposed by American neurologist Samuel Orton (Habib, 2003), and later appropriated by Geschwind, was that lateralization of language

functions to the left hemisphere was delayed in dyslexics, preventing the prerequisites for learning to read from developing normally. The high incidence of left-handers and the mirror-writing phenomenon was taken as evidence for abnormal lateralization in these children. Geschwind and his colleague Galaburda (1985) proposed that cortical asymmetry was the key neurological aspect in dyslexia.

#### **1.4 CLINICAL SPECTRUM OF SPECIFIC READING DISORDER**

It is widely, though not universally, recognised that specific reading disorder is more frequent in males than in females (with ratios ranging from 2:3 to 4:5, depending on the study) and that it has a significant familial occurrence (Shaywitz, 2003; Shaywitz et al., 2002). Children with this condition have associated deficits in related domains, such as oral language (e.g., subtle difficulties in processing spoken language), writing abilities (dysgraphia and misspelling), mathematical abilities (dyscalculia), motor coordination (dyspraxia), postural stability and dexterity, temporal orientation (dyschronia), visuo-spatial abilities (developmental right-hemisphere syndrome), and attentional abilities (hyperactivity and attention deficit disorder) (Fawcett, Nicolson, & Dean, 1996; Gross-Tsur, Shalev, Manor, & Amir, 1995).

In addition to these multiple possible interrelations and associations, developmental reading disorder is “specific” to reading difficulties alone, as it is experienced in the presence of intact general intelligence (normal or above normal non-verbal IQ). Verbal and performance IQ may show usual (verbal < performance) or reversed dissociation. Such dissociation is taken as a good argument in favour of a “developmental lesion” affecting separately one or several brain circuits or modules specialised in various aspects of cognitive function. Presence of comorbidity also suggests a common origin involving

either genetic factors or pre-natal environmental influences, or both. Comorbidity also has important diagnostic as well as prognostic significance, influencing both evaluation and remediation of the reading disorder.

One aspect of specific reading disorder that has received particular attention during the last two decades is spoken language impairment. A considerable proportion of children with specific reading disorder experiences difficulties relating to one or more aspects of their spoken language development. These difficulties range from oral language-processing difficulties and word-finding difficulties to more subtle speech perception and speech articulation difficulties (Sawyer, 1992; Scarborough, 1990). One of the most widely recognised oral language concomitants of reading difficulty is a task known as “rapid automated naming”, which requires children to rapidly name the pictures presented on a sheet recurrently and in a random order (Habib, 2003).

Errors in oral language abilities, and later in reading, provide insight into the difficulties experienced by children with specific reading disorder. Some of the errors that these children make when reading include (among others):

- Very slow progress in acquiring reading skills;
- A lack of strategy relative to reading new words;
- Trouble reading unknown words;
- Difficulty reading small sight words, such as *that, an, in, was*;
- Omitting, substituting and/or mispronouncing parts of words;
- Oral reading that appears laboured and effortful;
- Poor intonation while reading;
- Dependence on context of the text to read the word;

- Substitution of words with the same meaning, for example, *house for home*;
- Spelling and writing difficulties; and
- Avoidance of reading for pleasure.

Children with specific reading disorder display poor grapheme–phoneme conversions. This dysfunction is the core one in reading difficulty because grapheme–phoneme conversion is a critical stage of learning to read (Frith, 1985). The two main aspects of neurological dysfunction that occur during this stage relate to visual-perceptual and phonological processes. Besides cases of obvious dysgraphia due to associated motor and/or coordination/dexterity impairment, the written work of these children is impaired. Errors such as phonemic errors in the transcription from oral to written form of letters and syllables, defective spatial arrangement of letters, inversions, omissions and substitutions of letters and/or syllables and weak grammatical development are evident in the writing sample.

Children with specific reading disorder also demonstrate a wide variety of other symptoms. They are often slow to learn to crawl, walk and speak. They also tend to be somewhat clumsy, and may never learn to ride a bicycle (Stein & Talcott, 1999). Fawcett et al. (1996) documented a tendency in children with reading difficulty to display mild cerebellar signs, such as muscle hypotonia, poor balance and slow tapping. Other problems noticed are difficulty with distinguishing left from right, timing and sequencing, unpunctuality and a tendency to mix up the order of the days of the week and months in a year (Stein & Talcott, 1999). This multitude of possible manifestations makes it imperative to bring rational approach to understanding the disorder and to providing remediation.



## 1.5 BRAIN STRUCTURES INVOLVED IN READING

Our understanding of the brain structures involved in normal development of reading stems from research conducted over several years. Early theorists based their findings on post-mortem studies. The advent of the more recent non-invasive imaging techniques has produced understanding of how the brain responds to reading tasks and how this response gets shaped from a beginning reader to a skilled reader. This information, in turn, has allowed a deeper understanding of how normal reading development occurs. Seeing how a disabled reader differs from a normal reader relative to recruitment of brain regions during reading has led to our current knowledge of and theorising about reading disorder.

Some researchers maintain that disruptions at the cellular level occur during the early stages of foetal development. The proponents of this theory argue that the neurons responsible for carrying out phonological processing do not form networks to the extent that is required to allow this functioning to proceed smoothly (Galaburda, Menard, & Rosen, 1994; Shaywitz, 2003). As a consequence, disruption in reading and spelling are noticed in the absence of observable lesions or structural damage. The variation in the deficit profile noticed in children with specific reading disorder is attributed to genetically programmed error in the neural networks responsible for phonological processing and therefore reading (Shaywitz, 2003).

The most common methods used to identify deficits in children with specific reading disorder are to compare these children on various parameters with normal readers. Comparative studies of this kind have shed light on the nature of the disorder. Differences include biochemical variants in temporal and parietal lobes (Rae et al., 1998) less myelin in these same regions (Klingberg et al., 2000) and structural anomalies in the insula (Cao, Bitan, & Booth, 2008; Frackowiak et al., 2004), planum temporale,

cerebellum and Heschl's gyrus (Ramus, 2003). Functional studies using fMRI, PET and magneto-encephalogram while the subjects perform reading-related tasks suggests that people with dyslexia may exhibit abnormal activation during sensory visual processing (Eden, VanMeter, Rumsey, & Zeffiro, 1996; Schulte-Korne, Deimel, Bartling, & Remschmidt, 2004), visual speed discrimination thresholds (Demb, Boynton, & Heeger, 1998), rapid acoustic processing (Nagarajan et al., 1999; Temple et al., 2003) auditory processing (Schulte-Korne et al., 2004), orthographic processing (Flowers, Wood, & Naylor, 1991; Temple et al., 2003), phonological processing (Frackowiak et al., 2004; Paulesu et al., 1996; Shaywitz et al., 1998) and automatised phases of motor skill acquisition (Baillieux et al., 2008; Howard, Howard, Japikse, & Eden, 2006; Nicolson & Fawcett, 1990). Evidence therefore suggests that specific reading disorder is best understood as a consequence of failures in multiple brain regions in a complex, functional reading system and of a functional disconnection among these regions (Horwitz, Rumsey, & Donohue, 1998; Paulesu et al., 1996).

As noted above, our initial understanding of deficits and anatomical dysfunctions in the brain came from examinations of brains of deceased individuals with a history of reading difficulties. Such examinations showed a number of differences between these brains and the brains of people who did or did not have reading disorder. The differences primarily noticed were in the structures associated with language on the left side of the brain. These differences coincided with hypotheses offered by neurologist Norman Geschwind 20 years earlier that reading difficulty results from damage to, or improper development of, language regions in foetal life. These findings played an important role in focusing attention on the neurological substrate of dyslexia. Subsequently, functional

imaging studies have provided valuable information regarding the functioning of the brain, especially during the act of reading. Imaging studies have identified at least two neural pathways for reading: one for beginning readers for slowly sounding out words, and another that is a pathway for skilled readers.

### **1.5.1 Early Studies**

Galaburda, Sherman, Rosen, Aboitiz and Geschwind (1985) studied a number of brains of known individuals with dyslexia post mortem and found that they had obvious neuropathological abnormalities that probably occurred towards the end of the second trimester of foetal development, at around 24 weeks gestation when, the cerebral cortex is developing and folding most rapidly. The most common of these abnormalities were cortical ectopias occurring mainly in the temporo-parietal and frontal association areas in both hemispheres, but particularly on the left hemisphere.

Other abnormalities of development were also seen in the brains of individuals with dyslexia. These included microgyrias, which are tiny aberrant in-foldings of the cortex. Glial scars were found in the brains of females with dyslexia, suggesting that, in females, injury in cortical development may take place a little later than it does in males. Examination of the visual and auditory relay nuclei in the thalamus revealed selective disruption of the large magnocellular neurons (Livingstone, Rosen, Drislane, & Galaburda, 1991). Hynd, Semrond-Clikan, Lorys, Novey, & Eliopoulos (1990) found that the planum temporale were relatively symmetrical in the brain of a child with reading. However, in a normal brain, the left planum temporale was 10 times larger than the right.

### 1.5.2 Imaging Studies

Early imaging studies aimed at identifying the neural systems underlying reading disorder were undertaken using PET (positron emission tomography). Gross-Glenn and colleagues (1991) studied glucose metabolism while subjects were involved in serial reading of single words. The researchers found decreases in the normal asymmetries of the frontal and occipital regions in the dyslexic group. The control group, however, showed greater leftward asymmetry in the lingual gyrus, but more rightward asymmetry in the frontal regions. In another study, conducted by Hangman, Wood, Buchsbaum, Tallal, Flowers, & Katz (1992), regional cerebral blood flow (rCBF) was found to be higher in the bilateral medial temporal lobes in dyslexics engaged in a task involving auditory syllable discrimination. These two studies, however, “were characterized by the absence of baseline conditions and limitations of statistical power necessary to reliably identify population differences” (Frackowiak et al., 2004).

Flowers et al. (1991) used xenon inhalation to study rCBF among dyslexic children endeavouring to identify correctly spelled four-letter words presented orally. Flowers and colleagues found that reading impairment related to excess blood flow to the posterior temporo-parietal region. In their study, Rumsey et al. (1992) asked their subjects to listen to paired presentations of two-, three- and four-syllable words. The subjects had to press a button if the pair rhymed. The baseline task was to identify a low tone among a series of distracters. The authors found that, compared to the control group, the dyslexic group performed more poorly and showed less activation in the left middle temporo-parietal region (including the angular gyrus).

In 1994, Rumsey et al. investigated the role of the right hemisphere in dyslexia using a task of tonal memory. Individuals with reading disorder and control subjects, matched for age, gender, handedness, education level and performance IQ, listened to paired sequences of tones. The task was to press a button if the pair was identical, with rest as the baseline condition. The dyslexic group made more errors than the control group and failed to show activation in the right superior temporal gyrus, and in the right middle and inferior frontal gyrus. Rumsey and colleagues attributed the differences in activation to rapid temporal processing deficits in the dyslexic group.

Paulesu et al. (1996) contrasted neural activation in five individuals with dyslexia and five control participants during a rhyme judgment and working memory task. The dyslexics showed activation of Broca's area during rhyme judgment and Wernicke's area during the working memory task, while the control group showed activation of the insula in addition to the two areas activated in individuals with dyslexia. The authors concluded that dyslexia was a disconnection syndrome, with the insula bridging the gap between these two regions. The role of insula has not been highlighted in other studies (see, for example, Frackowiak et al., 2004).

The neural correlates corresponding to the alphabetic/orthographic processing in the reading system has been reliably associated with the occipito-temporal region of the left hemisphere (Ramus et al., 2003; Shaywitz & Shaywitz, 2005). According to an analysis by Cohen, Campbell, and Yaghai (1989), there is a whole hierarchy of representations in this region, with the more posterior areas (in the occipital lobe) being specifically visual and perhaps related to processing of low-level visual features and letter-shapes. The representations seem to become progressively more abstract as they get

more anterior in the ventral temporal lobe: the mid-portion of the left fusiform gyrus appears to support representations of abstract letter strings of both words and non-words, whereas the more anterior portion seems to be more specific to words (however, in many studies this distinction is not explicitly made). The reading-related areas are embedded within a larger ventral object-recognition system with similar perceptual gradients (Ramus et al., 2003). From the fusiform gyrus, the hierarchy of more and more abstract orthographic representations seems to progress over the posterior portions of the inferior and medial temporal gyri, with the latter being a possible locus for the orthographic lexicon (Simos et al., 2002).

In developmental terms, Shaywitz and colleagues have shown, across a large group of children ages 7 to 17, that activation in the occipital-temporal area increases when reading becomes skilled and automatic (Shaywitz et al., 2002; Shaywitz & Shaywitz, 2005; Ramus et al., 2003). This finding is consistent with the idea of the progressive formation of alphabetic and orthographic representations. There is reliable evidence that these same areas are hypo-activated in both child and adult with reading disorder during reading tasks (Brunswick, McCrory, Price, Frith, & Frith, 1999; Shaywitz et al., 1998; Shaywitz et al., 2002). This evidence does not mean that a dysfunction in these areas is the cause of reading difficulty; rather, it is compatible with the prediction that orthographic representations develop abnormally as a result of the phonological deficit.

The other major component in the reading system is the temporo-parietal junction, including the posterior superior temporal gyrus (STGp), the angular gyrus and the supra-marginal gyrus, predominantly in the left hemisphere. A clear decomposition of this large region into functional areas has not been achieved yet, but it is assumed that the angular

gyrus is responsible for processing orthographic lexicon while the superior temporal lobe and the supramarginal gyrus is involved in sub-lexical processing (Shaywitz et al., 2002). The STGp is thought to be associated with computing grapheme–phoneme correspondences (Simos et al., 2002). The activation of the temporo-parietal junction in reading occurs after that of the occipito-temporal areas (Simos, Brier, & Fletcher, 2000; Simos et al., 2002), consistent with the view that visual/alphabetic processing precedes phonological processing and lexical access.

Children seem to activate the left STGp more than adults do when engaged in tasks requiring word reading (Booth et al., 2002), a finding that is again consistent with the idea that children rely more on alphabetic and less on orthographic strategies. Furthermore, Ramus et al. (2003) found that activation in the neighbouring left posterior superior temporal sulcus correlated with a measure of phonological awareness in children. In contrast, dyslexic children and adults (with a history of specific reading disorder) have consistently been found to demonstrate, compared to controls, decreased activation of the temporo-parietal junction (Paulesu, Frith & Frackowiak, 1993; Simos et al., 2002; Temple et al., 2002; Temple et al., 2000). This finding is consistent with the idea that children and adults with reading disorder have a phonological deficit and difficulties with grapheme–phoneme processing. Interestingly, children with reading disorder appear to demonstrate increased activation of the right hemisphere while reading.

The increased activation, not noticed in non-disabled controls, is interpreted as compensation for difficulties in reading (Shaywitz et al., 1998; Shaywitz & Shaywitz, 2005; Simos et al., 2002). A remediation study showed that, after completing a

phonological awareness training program, children with specific reading disorder improved behaviourally. They also were able to involve their left STGp in non-word reading tasks significantly more after treatment (Simos, et al., 2002). The better phonological processing abilities brought left hemisphere activation closer to that of the control group.

According to Temple and colleagues (2003), the specific reading disorder experienced by children could be ascribed to a congenital dysfunction of the left temporo-parietal junction, resulting in disrupted sub-lexical phonological representations and difficulties in learning alphabetic reading. This hypothesis is compatible with some anatomical data indicating structural and metabolic anomalies in these areas of dyslexics' brains (Brown et al., 2001; Rae et al., 1998; Ramus et al., 2003).

Many areas of the brain of people with dyslexia have been found to be "different", on average, from those of non-dyslexics (Habib, 2003). However, the functional significance of these differences has yet to be established. One hypothesis relative to this difference is that there is a partial disconnection of left temporo-parietal areas from the temporo-occipital language areas (Paulesu et al., 1996). This premise is supported by diffusion tensor imaging showing disruption in the underlying white matter (Klingberg et al., 2000), and it is particularly interesting in the light of evidence that, unlike the functional activations in controls' angular gyrus, functional activations in dyslexics' angular gyrus fail to correlate with activations in the ventral orthographic system (Horwitz et al., 1998; Simos et al., 2000).

In recent years, there has been an upsurge in the number of studies that suggest the involvement of the cerebellum in specific reading disorder. In a series of studies,



Nicolson and Fawcett and their colleagues developed a strikingly different account that postulated a failure of automatization as the primary deficit in specific reading disorder (Baillieux et al., 2008; Nicolson, Fawcett, & Dean, 2001). Baillieux and colleagues propose an alternative hypothesis to the existing cerebellar hypothesis. In their recent (2008) study, they found diffused cerebellar dysfunction in a group of children with dyslexia. They proposed that the reading difficulties in dyslexia arise as a consequence of information processing deficits within the cerebellum.

Over the past 20 years, studies have consistently shown that children (Shaywitz & Shaywitz, 2005) and adults (Bruck, 1992; Shaywitz et al., 2002) with specific reading disorder have difficulties in processing phonological aspects of words. Several studies involving use of functional imaging have implicated specific areas in the brain in reading disorder. These areas help differentiate a non-impaired reader from a disabled reader. Researchers have also shown that the functioning of these target areas changes subsequent to remedial training that focuses on phonological awareness (Shaywitz et al., 2005). The three areas of interest in the left hemisphere are (i) the large area surrounding the inferior frontal lobes, (ii) the angular gyrus, supramarginal gyrus and Wernick's area (encompassing the middle and posterior superior temporal lobes), and (iii) Broadman's area 37, referred to as the posterior temporal region or the temporo-occipital area. Other studies propose involvement of other structures, such as the magnocellular layer (Demb et al., 1998; Eden et al., 1996) and the cerebellum (Howard et al., 2006; Nicolson & Fawcett, 2001).

The extent to which these areas directly contribute to reading and how many of them are solely responsible for the reading difficulties seen in children are debatable. The

anatomical regions involved in specific reading disorder are still under investigation. However, current advances in technology have led to knowledge of which brain regions are involved when a person engages in reading. This understanding has led to a number of theories that attempt to throw light on specific reading disorder. The next section describes the most popular theories.

## **1.6 SPECIFIC READING DISORDER THEORIES**

It is now established that specific reading disorder is a neurological disorder with a genetic origin (Shaywitz & Shaywitz, 2005; Howard et al., 2006; Ramus et al., 2003). The precise nature of the disorder is not fully understood. There is agreement among researchers that the core problem in reading disorder is a functional impairment within the brain mechanism specialised for phonological analysis (Simos et al., 2002). Evidence suggests that specific reading disorder is best understood as the consequence of failures in multiple brain regions in a complex functional reading system (Berninger & Richards, 2002) and in functional disconnections among these regions (Horowitz et al., 1998; Paulesu et al., 1996).

Many explanations and theories have been put forth to explain this disorder. Because the disorder is termed neurological in nature, these delineate the functioning and the structures of the brain involved in the disorder.

### 1.6.1 Phonological Deficit Theory

The phonological deficit theory postulates that children with specific reading disorder have a specific impairment in the representation, storage and/or retrieval of speech sounds. This theory explains the presence of a reading impairment by appealing to the fact that learning to read an alphabetic system requires learning the grapheme–phoneme correspondence, that is, the correspondence between letters and the constituent sounds of speech. If these sounds are poorly represented, stored or retrieved, the learning of grapheme–phoneme correspondences are affected accordingly (Bradley & Bryant, 1978; Ramus et al., 2003; Snowling, 1981).

Although theorists have different views about the nature of the phonological problems, they agree on the central and causal role of phonology in dyslexia. The phonological deficit theory postulates a straightforward link between a cognitive deficit and the behavioural problem to be explained. At the neurological level, it is usually assumed that the origin of the disorder is a congenital dysfunction of the left-hemisphere perisylvian brain areas underlying phonological representations, or connections between phonological and orthographic representations (Cao, Bitan, & Booth, 2008).

Support for the phonological deficit theory comes from evidence that dyslexic individuals perform particularly poorly on tasks requiring phonological awareness, that is, conscious segmentation and manipulation of speech sounds. Anatomical work (Galaburda, Sherman, Rosen, Aboitiz & Geschwind 1985; Geschwind & Galaburda, 1985) and functional imaging studies support a perisylvian dysfunction as a basis for the phonological deficit (Brunswick et al., 1999; Paulesu et al., 1996, 2001; Shaywitz & Shaywitz, 2005; Shaywitz et al., 2002; Temple et al., 2001). Lundberg and colleagues

(Lundberg, Frost, & Peterse 1988) showed improved reading abilities in children previously trained in such exercises; these observations are the basis of the widespread use of oral language exercises for the rehabilitation of reading and spelling disorders.

An important concept of the phonological processing theory is that there is a deficit at the level of phoneme representation itself. For instance, several researchers have found that children with reading disorder are poorer than age-matched controls (and controls matched for reading age) at tasks that require processing of subtle differences between phonemes that are acoustically similar to one another. This is evident in tasks requiring children to categorize sounds such as “ba” and “da”. Studies, among them those by (Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Habib, 2000), have shown a deficit in this task among a number of dyslexics. The deficit is generally found for items situated close to the intercategory boundary, especially articulatory oppositions (/ba/-/da/; /da/-/ga/) or less-often voice-onset oppositions such as /ba/-/pa/ (Manis et al., 1997).

Manis and colleagues (1997) showed phonological awareness deficits in a subgroup of children with dyslexia. The authors concluded that perceptual difficulties cause inadequate representations of phonemic units, which, in turn, prevent children with dyslexia from using and manipulating phonological information. The end result is impairment in the ability to read.

It is sometimes argued that phonology and reading are two sides of the same coin, in the sense that the phoneme awareness is enhanced by reading skills as well as the other way around (Ramus, 2003). Others have argued that children with specific reading disorder have at least two other major phonological problems beyond phonological awareness, in rapid naming (of pictures, colours, digits, and/or letters) and verbal short-

term memory, neither of which can be said to rely on reading (Ramus, 2003; Snowling et al., 2000). Evidence for poor verbal short-term memory and slow automatic naming in children with specific reading disorder points to a more basic deficit in phonological representations, access and retrieval (Snowling, Bishop, & Stothard, 2000). A major debate in the recent literature is whether these are independent phonological deficits or whether they are different manifestations of a single underlying deficit. Evidence indicates that phoneme awareness and rapid naming deficits are relatively independent and additive (Ramus, 2001). Phonological awareness, rapid automatic naming and verbal memory are grouped under a broader category named phonological processing abilities. However, it is clear the phonological processing includes several other processes in addition to those already mentioned, namely awareness, naming and memory. Many aspects of phonology consequently remain to be investigated in specific reading disorder (Ramus, 2001, 2003).

A number of research groups have used fMRI to examine the functional organization of the brain for reading in non-impaired (NI) and impaired (DYS) readers. Rumsey et al. (1992) assessed word and non-word reading in 17 dyslexic and 14 control male adults. The reading disorder group had experienced reading difficulties since childhood and were of average intelligence. The control group was matched for handedness, age, social class and IQ. The authors used whole brain analysis to measure rCBF with PET during two pronunciation tasks (one requiring the reading of pseudo-words and the other requiring the reading of irregular real words) and two lexical decision tasks. In both the reading and lexical decision tasks, the dyslexic participants showed reduced rCBF in bilateral mid-posterior temporo-parietal cortex, including

angular/supramarginal region. Normal activation was reported for the same tasks in the left inferior frontal regions. This observation was the same in both word and pseudo-word conditions. Based on their findings, the authors hypothesised a bilateral involvement of posterior temporal and parietal cortex in dyslexia. They also hypothesised that a common impairment underlies the difficulties experienced by dyslexics in reading real and pseudo-words.

Shaywitz et al. (1998) found significant differences in brain activation patterns between dyslexics and non-impaired readers. Differences were observed during non-word rhyming tasks. The researchers found decreased activation in the posterior superior temporal gyrus and the angular gyrus with a concomitant increase in activation in the inferior frontal gyrus anteriorly.

Shaywitz et al. (2002) used functional magnetic resonance imaging (fMRI) to study 144 right-handed children (boys and girls) as they read pseudo-words and real words. They found significant differences in brain-activation patterns during phonologic analysis in non-impaired children compared to dyslexic children. Specifically, non-impaired children showed significantly greater activation than children with reading disorder in bilateral inferior frontal and parieto-temporal regions, left medial temporal-occipital and left superior-temporal regions. Further analysis of Shaywitz and colleagues' data suggested that, in individuals with dyslexia, age correlated positively with bilateral inferior frontal gyrus on non-word reading tasks. For the non-impaired group, the correlation was negative. On a category judgment task, the non-impaired group showed a positive correlation between age and activation in the inferior frontal gyrus and right pre-

central sulcus while the reading disorder group showed a negative correlation with age and activation in the right inferior frontal gyrus.

Data from other studies have shown left hemisphere posterior brain systems failing to function properly during reading (Brunswick et al., 1999; Horwitz et al., 1998; Rumsey et al., 1992; Salmelin et al., 1996; Seki et al., 2001; Shaywitz et al., 2002; Temple et al., 2000) as well as during non-reading visual processing tasks (Demb et al., 1998; Eden et al., 1996).

In a recent study involving imaging, Cao et al. (2008) demonstrated that children with specific reading disorder had deficits in integrating orthography and phonology using left inferior parietal lobule. Difficulties were also noticed in the modulatory effects of the left inferior frontal gyrus when the children carried out phonological segmentation tasks. The authors hypothesised that when orthographic and phonological information conflicts, children with reading disorder fail to stimulate the indirect pathway connecting the posterior and anterior language-processing regions.

Cao et al. (2008) also compared the performance of children with specific reading disorder with a non-impaired control group. The control group showed adequate modulatory effects of the left inferior frontal lobe on the left inferior parietal lobe when faced with conflicting orthographic and phonologic tasks. The increased correlation between skilled reading and modulatory effect of the anterior regions over the posterior regions in skilled readers was taken as evidence of resolution of conflict. Thus, absence of conflict resolution in the reading disorder group was taken as evidence of difficulties in understanding the relationship between orthography and phonology.

Although phonological deficit theory is the most popular of the theories attempting to explain the basis of deficits in specific reading disorder, it is not without its critics. Proponents of other theories indicate that this theory alone is not enough to explain all the difficulties noticed in children with specific reading disorder. A small group of children with the disorder have other deficits, such as sensory-motor deficits, that are not explained by phonological deficit theory.

### **1.6.2 Rapid Auditory Processing Theory**

The most obvious way to challenge the specificity of the phonological deficit is to postulate that it is secondary to a more basic auditory deficit. This is the claim of the rapid auditory processing theory, which specifies that the deficit lies in the perception of short or rapidly varying sounds (Tallal, 1980). The hypothesis posits that children with specific reading disorder have language problems that result from their inability to perceive the rapid acoustic elements included in human speech, namely the formant transitions whose duration is as short as a few tens of milliseconds. Support for this theory arises from evidence that children with specific reading disorder perform poorly on a number of auditory tasks, including frequency discrimination (Ramus et al., 2003) and temporal order judgment (Gaab, Gabrieli, Deutsch, Tallal, & Temple, 2007; Nagarajan et al., 1999; Tallal, 1980; Tallal & Gaab, 2006).

Abnormal neurophysiological responses to auditory stimuli have been demonstrated (Nagarajan et al., 1999; Temple, 2002). The failure to correctly represent short sounds and fast transitions causes further difficulties, especially when such acoustic events are the cues to phonemic contrasts, as in /ba/ versus /da/. There is also evidence that dyslexics may have poorer categorical perception of certain contrasts (Ramus, 2003).



In this view, the auditory deficit is therefore the direct cause, during the course of development, of the difficulty in reading.

Three neuroimaging studies of auditory processing deficits in specific reading disorder have been reported. The first, conducted by Rumsey et al. (1992), reported reduced right hemisphere activation for children with dyslexia during a tonal memory task.

In the second study, McCrory, Frith, Brunswick, and Price (1999) considered eight subjects with dyslexia (along with six non-impaired subjects matched for age and general ability) using PET during three conditions: rest, repeating real words, and repeating pseudo words. In both groups, the rest condition compared to the other two conditions showed bilateral activation of areas associated with auditory processing of speech sounds. No difference between the two groups was found. However, when compared with the control group, the group of subjects with specific reading disorder showed decreased activation in the right superior temporal lobe (notably BA 22), right post-central gyri and left cerebellum. The activation in this area is known to reduce when non-impaired participants actively attend to phonetic structure of speech. The authors concluded that the decreased right hemisphere activation observed in the dyslexic group indicates a compensatory processing; i.e. they exhibit greater effort in processing phonological components of speech compared to non impaired individuals suggesting the process is effortful (as against automatic in non-impaired individuals).

Temple et al. (2003), authors of the third study, presented stimuli containing rapid and slow auditory transitions to dyslexic and control participants. The participants were required to press a button if they judged the stimulus to be high pitched. The stimuli were

non-linguistic in nature. The authors reported reduced activation in the dyslexic group compared to the control group, in the left pre-frontal region (BA 46/9/10). They also documented that the left pre-frontal response to rapid stimuli correlated with auditory processing ability. The authors trained a subset of dyslexics on auditory processing. After training, the participants showed changes in brain activation in response to rapid stimuli; some even showed improved auditory processing and auditory language comprehension tests after the training.

Neurological accounts of specific reading disorder usually ascribe at least some of the symptoms observed to a left-hemisphere dysfunction. That the left hemisphere is associated with the role of rapid processing of brief stimuli is also widely admitted (Habib, 2000). Adult aphasics with acquired left-hemisphere damage are also impaired on rapid processing tasks. The degree of impairment is correlated with the extent of the language impairment (Tallal & Newcomb, 1978). In addition, older adults who often report difficulty understanding speech despite normal hearing, exhibit a temporal sequencing decrement (Habib, 2000).

There is thus converging evidence that the left hemisphere is pre-wired to support the function of processing transient sensory events, especially when these events become meaningful through their temporo-spatial characteristics. There are numerous circumstances in clinical practice where children with specific reading difficulty seem to have trouble with various aspects of temporal processing. Severe delays in time duration awareness, sequential naming problems for concepts pertaining to time (such as the days of the week), errors in time relocation of memories and vagueness of temporal distance or remoteness appreciation are some of the deficits noticed (Habib, 2000). Whether these

levels of “temporal features” impairment depend on the same mechanism is not yet known, but they do provide the basis of a reasonable and testable hypothesis.

Walker, Hall, Klein, and Phillips (2007) studied the performance of 120 individuals on eight temporal processing tasks and five language/reading tasks. They found support for the notion that there is a separable auditory and visual perceptual contribution to phonological and orthographic reading development. The authors argued that the term “temporal processing” encompasses fundamentally different sensory or cognitive processes that may contribute differentially to language and reading performance, and that may have different developmental trajectories and be differentially susceptible to pathology.

### **1.6.3 The Visual Theory**

The visual theory (Livingstone et al., 1991; Lovegrove, Bowling, Badcock, & Blackwood, 1980; Stein & Walsh, 1997) reflects another line of thought in understanding specific reading difficulty. This line of thought considers that a visual impairment gives rise to difficulties with the processing of letters and words on a page of text. These difficulties may take the form of unstable binocular fixations, poor convergence (Cornelissen et al., 1998; Habib, 2000) or increased visual crowding (Spinelli et al., 2002). The visual theory does not rule out a phonological deficit, but emphasises a visual contribution to reading problems, at least in some individuals with specific reading disorder.

At the biological level, the proposed aetiology of the visual dysfunction is based on the division of the visual system into two distinct pathways with different roles and properties: the magnocellular and parvocellular pathways. The theory postulates that the

magnocellular pathway is selectively disrupted in certain individuals, leading to deficiencies in visual processing and, via the posterior parietal cortex, to abnormal binocular control and visuospatial attention (Hari, Renvall, & Tankskanen, 2001; Stein & Walsh, 1997). Evidence for the magnocellular dysfunction comes from anatomical studies showing abnormalities of the magnocellular layers of the lateral geniculate nucleus (Livingstone et al., 1991), psychophysical studies showing decreased sensitivity in the magnocellular range (that is, low spatial frequencies and high temporal frequencies) in dyslexics (Cornelissen et al., 1995; Lovegrove et al., 1980) and brain imaging studies (Eden et al., 1996).

The debate on visual deficits is articulated around three questions that are similar to those asked about auditory deficit (Ramus, 2003). First, do visual disorders cause specific reading disorder? Second, do those visual disorders have a magnocellular origin? And, third, what proportions of children with specific reading difficulty are affected? With the exclusion of major ophthalmologic disorders, it seems plausible that more subtle visual deficits might have an impact on reading. Perhaps the clearest example is visual stress (Ramus et al., 2003), a condition that provokes visual distortions and sometimes leads to impaired reading fluency. This condition can be improved by using coloured overlays or glasses (Ramus et al., 2003). Other visual problems that are often mentioned in the context of specific reading disorder include binocular fixation instability and poor vergence control (Stein, 2001), increased crowding (Spinelli, 2002), and slight visuospatial attention deficits (Hari & Renvall, 2001).

Although these are all plausible proximal causes of reading impairment, both prevalence and relationship to reading retardation remains debated, especially as a

phonological deficit often accompanies visual disorders (Ramus, 2003). Whether a magnocellular dysfunction is the underlying cause of visual impairments is not clear. Several studies have provided evidence that children with specific reading disorder have elevated detection thresholds or abnormal visual-evoked potentials for stimuli in the spatial and temporal ranges of the magnocellular system (Ramus et al., 2003).

Reports in recent literature point to disputes in whether some of the stimuli used in the studies actually tap the magnocellular system (Skottun, 2005). A growing number of studies report findings that are inconsistent with a visual deficit that is specific to the magnocellular system (Amitay et al., 2001; Ramus et al., 2003). These studies have often found that visual deficits, when present, cover the whole range of spatial and temporal frequencies. Questions have also been raised as to whether group differences could be explained by attention or memory rather than sensory deficits (Ben-Yehudah et al., 2001; Stuart, McAnally, & Castles, 2001). Moreover, visual deficits seem to be restricted to a subset of children with specific reading disorder; in seven recent studies displaying individual data, 29% of poor readers had elevated visual thresholds in the target conditions (Ramus, 2003; Ramus et al., 2003). Finally no demonstration has been provided that magnocellular dysfunction, when present, engenders visual problems that are more proximal to reading, such as visual instability, crowding and stress (Ramus, 2003; Ramus et al., 2003).

To summarise, a small group of children with specific reading disorder have visual problems. Visual stress appears to be dissociated from the phonological deficit, and is therefore a possible independent cause of specific reading disorder. However, the

underlying biological cause of the visual disorders and their precise impact on reading still needs to be elucidated.

#### **1.6.4 The Magnocellular Theory**

Other hypotheses exist concerning the neurological origin of specific reading disorder, in particular those related to alternative cognitive theories (auditory, visual). The visual deficits seen in children with specific reading disorder have been interpreted in the context of an impaired magnocellular system (Frackowiack et al., 2004). The magnocellular system is associated with high temporal resolution and sensitivity to low contrast and low spatial resolution. Poor contrast sensitivity (Lovegrove, Bowling, Badcock, & Blackwood, 1980), temporal judgement and visual instability (Eden, VanMeter, Rumsey, & Zeffiro, 1996) have been taken as evidence of dysfunction within this system in individuals with specific reading disorder (Stein & Talcott, 1999). Stein and colleagues (1999) hypothesise that magnocells in all sensory pathways are deficient, leading to visual disorders causing reading difficulties, and to auditory disorders causing the phonological deficit.

Reading requires fast and accurate processing of transient visual and auditory stimuli, functions for which large neurons, known as magnocellular neurons, are specialised. The magnocellular hypothesis claims that many poor readers have impaired function of the visual magnocellular system, which correlates with their reading impairment, whereas good readers have high magnocellular sensitivity (Stein & Talcott, 1999; Stein & Walsh, 1997). Although there is no clearly defined magnocellular pathway in the auditory system as there is in the visual system, there is an analogous set of large

auditory neurons that are specialised for following changes in the frequency and amplitude of sound. Children with specific reading disorder are reported to have a reduced sensitivity in the transient auditory system. The theory proposes that the reduction in the sensitivity within the system is responsible for the impaired phonological ability (Stein & Talcott, 1999). Thus, the magnocellular hypothesis postulates that impaired readers have lower sensitivity to dynamic visual and auditory stimuli as a result of slightly impaired development of large neurons and that this may explain not only their visual problems when attempting to read but also their phonological deficit.

In the eye and optic pathways, large (magno) and small (parvo) retinal ganglion cells are distinguished. The magnocells are specialized for following changes in sensory and motor signals throughout the nervous system. They can follow rapid changes in illumination, and also respond to low light and contrast levels. The axons of the magnocells are large and thickly myelinated, so they conduct signals rapidly to the first visual relay in the brain, the lateral geniculate nucleus (LGN) of the thalamus. From there, the relay of information reaches the primary visual area in the cortex. After this, magnocellular signals intermingle with parvocellular signals, and the results are distributed to all the visual processing regions of the cerebral cortex.

There are two main output streams from the primary visual cortex. One pathway receives both parvocellular and magnocellular input and projects forward to the inferior temporal cortex (IFT). The IFT is mainly responsible for analysis and recognition of forms and patterns, and so is often known as the “what” stream. The other pathway, known as the “where” stream, is dominated by the magnocellular input and passes into the posterior parietal cortex (PPC). The main function of this stream is to help control the

movements guided by visual input. In addition to this pathway via the cerebral cortex is the visual magnocellular system. This provides the main visual input to the brain-stem structures controlling reflex and other movements. The sensitivity of the magnocellular component to visual processing can be assessed psychophysically using stimuli, which selectively stimulate it. Tests have shown that the visual responses mediated by the magnocellular system are slightly, but significantly, impaired in impaired readers when compared with normal readers.

Eden et al. (1996) reported a failure of a group of six volunteers with dyslexia to activate V5/MT while viewing low-contrast moving dots. In the control task, participants were required to look at a stationary pattern. A single subject analysis indicated that all the control subjects showed bilateral activation of V5/MT, whereas only one participant showed bilateral activation. No difference was found between the two groups in the control condition, suggesting that there were no visual deficits in the group with dyslexia. The authors interpreted their results in the context of the magnocellular hypothesis, which accounts for the visual and phonological processing deficits seen in the group with dyslexia.

Demb et al. (1998) investigated the magnocellular pathway in specific reading disorder using fMRI. Behaviourally, the participants with specific reading disorder showed poor speed-discrimination thresholds. Unlike in the earlier (Eden et al., 1996) study, the group with specific reading disorder showed bilateral activation of the V5/MT under low-mean luminance conditions. However, the response of the group with specific reading disorder was found to be significantly lower in the MT and adjacent motion-sensitive areas. In a high-mean luminance condition, no difference was found between



disabled and non-disabled readers. Given that the low-mean luminance emphasises the magnocellular pathway, the authors concluded that the specific reading disorder is caused by disruption in the magnocellular pathway.

Beyond the criticism already mentioned concerning the prevalence and the causal role of those sensory deficits, the magnocellular theory faces more specific challenges. In particular, it predicts that the sensory deficits of individuals with specific reading disorder will be observed for stimuli in a certain range of spatial and temporal frequencies characteristic of the response domain of magnocells. In the auditory domain, this prediction translates into the hypothesis of a “rapid auditory processing” deficit proposed by Tallal (1980). The empirical evidence is highly contradictory, split between findings consistent and inconsistent with the theory (Ramus, 2003; Skottun, 2000).

### **1.6.5 The Cerebellar Theory**

Yet another view is presented by the automaticity/cerebellar theory of specific reading disorder (Howard, Howard, Japikse, & Eden, 2006; Nicolson & Fawcett, 1990; Nicolson, Fawcett, & Dean, 2001). Here, the biological claim is that the cerebellum of children with specific reading disorder is mildly dysfunctional and that a number of cognitive difficulties ensue as a consequence. First, the cerebellum plays a role in motor control and therefore in speech articulation. It is postulated that retarded or dysfunctional articulation will lead to deficient phonological representations. Second, the cerebellum plays a role in the automatization of over-learned tasks, such as driving, typing and reading. A weak capacity to automatise will affect, among other things, the learning of grapheme–phoneme correspondences.

Support for the cerebellar theory comes from evidence of poor performance of individuals with specific reading disorder in a large number of motor tasks (Fawcett et al., 1996), dual tasks demonstrating impaired automatization of balance (Nicolson & Fawcett, 1990), and time estimation, a non-motor cerebellar task (Nicolson, Fawcett, & Dean, 1995). Brain imaging studies have also shown anatomical, metabolic and activation differences in the cerebellum of impaired readers (Brown et al., 2001; Nicolson, Fawcett, & Dean, 2001; Rae et al., 1998).

The cerebellar deficit theory meshes well with findings of perceptual impairments on magnocellular tasks in people with reading difficulty, because the cerebellum has close neuroanatomic links to magnocellular pathways (Stein & Talcott, 1999). As Beaton (2002) points out, most structural imaging studies have focused on cerebral asymmetry, with rather inconsistent findings from one study to the next. In a series of neuropathological studies, Galaburda and colleagues (1985) reported areas of abnormal cellular organisation (ectopias and polymicrogyria) in brains of children with specific reading disorder, predominantly affecting the left hemisphere. Finch and colleagues (2002) returned to the brains originally studied by Galaburda et al. (1985), comparing cell size and packing in the cerebellar cortex and related areas. Relative to the brains of the control group, the brains of the impaired readers had increased cell areas in the anterior and the medial posterior cerebellar cortex. Nicolson et al. (2001) have argued that the automatization deficit affects spoken as well as written language, as evidenced by slow response rates on rapid automated naming (RAN) tasks in individuals with specific reading disorder.

Chaixa, Fey, Zhang, and Tomblin (2007) analysed motor and attention abilities of 58 children with phonological dyslexia. A sub-group of children with dyslexia (40–57% of the total group) presented with motor impairments affecting co-ordination, balance and manual dexterity. The authors concluded that the motor deficits indicated a cerebellar dysfunction. A significant association between attention deficit and motor impairments, with a specific impact on balance and co-ordination deficits, was found in the study. The study showed that motor impairments were only comorbid symptoms. In addition, the results indicated a relationship between sustained attention and deficits on co-ordination and balance motor tests. The authors concluded that although their findings did not show a causal link between specific reading disorder and motor co-ordination and attention disorders, the role of cerebellar dysfunction in specific reading disorder cannot be ruled out.

In a recent study (Baillieux et al., 2008), functional neuroimaging (fMRI) was used to investigate ability to make noun–verb associations in a group of 15 children with specific reading disorder and 7 age-matched control subjects. The activation patterns between the group with specific reading disorder and the control group revealed differences in cerebral and cerebellar hemispheres. The control group showed bilateral activation in the frontal and parietal lobes and posterior cerebellum. The children with specific reading disorder had diffuse, widespread activations across frontal, parietal temporal and occipital lobes. The cerebellar regions that were activated by the dyslexic group were mainly in the cerebellar cortex. The authors attributed a difference in the cerebellar activation between the group with dyslexia and the control group during a semantic association task to a defect of the intra-cerebellar distribution of activity. They

suggested that reading difficulties associated with dyslexia occur due to a disorder in the transfer of processing information rather than a dysfunction of the cerebellum.

The cerebellar hypothesis has been attractive not only because it explained why some children persist in reading slowly despite learning basic letter-sound correspondences, but also because it accounts for difficulties outside the area of literacy, most notably in skilled motor behaviour. Furthermore, Nicolson and Fawcett (2001) identified the neurological basis of such a disorder in the cerebellum, which is regarded as playing a pivotal role in skill automatization.

Support for deficits involving the cerebellum comes from a study conducted several years ago by Stoodley and colleagues. Stoodley, Edward, and Stein (2006) reported implicit motor learning deficits in a group of adult dyslexics. They compared the performance of 21 controls (age 22 years, 10 months) with that of 19 adult dyslexics (23 years, 11 months) on a serial reaction-time task and found that the dyslexic group was significantly slower than the normal control group on the task and that they also showed a lower amount of learning on the task. This difference was found to be significant between good and poor readers. The authors concluded that certain brain regions, namely the pre-frontal cortex, basal ganglia, and the cerebellum, do not function optimally in dyslexics. Similar findings are reported by Howard et al. (2006). They studied 11 dyslexic college students and compared them with 12 non-dyslexic students for performance on two implicit learning tasks, one involving higher-order sequence learning and the other spatial-context learning. They found that the individuals with dyslexia showed impaired sequence learning but had superior contextual learning. The authors claimed that this difference supports the notion of a dysfunction in the fronto-striatal-cerebellar circuits for

sequence learning but that the medial temporal lobe (responsible for the spatial context learning) remains intact.

Nicolson et al. (2001) have argued that impairments of balance and muscle tone are a characteristic feature of many people with dyslexia. Three of the four cases described by Galaburda et al. (1985) had close relatives with clear literacy problems. Furthermore, genetic studies suggest that combined motor and language or reading deficits may constitute a distinct heritable phenotype (Bishop, 2002). Taken together, these findings suggest that the cerebellar deficit hypothesis may apply to particular forms of specific reading disorder that have a genetic basis.

## **1.7 OTHER ASSOCIATED CLINICAL FEATURES OF SPECIFIC READING DISORDER**

Children with specific reading disorder demonstrate a greater prevalence of comorbid behavioural and emotional difficulties than do children without reading disorder (Beitchman & Young, 1997; Willcutt & Pennington, 2001). In childhood, inattention and hyperactivity are found to be stronger correlates of academic problems than is aggression; by adolescence, however, antisocial behaviour and delinquency are clearly associated with underachievement (Hinshaw, 1992).

Some of the studies reviewed below have explored for comorbid condition in children with speech and language impairments or learning disorders in general while others have specifically explored for comorbid conditions with specific reading disorder. Most researchers agree that reading disorder has been more extensively studied than any other kind of learning disorder and that specific reading disorder is more commonly associated with a range of comorbid conditions. Some of these are reviewed below.

### 1.7.1 Behaviour Problems

Early epidemiological studies indicated that children with specific deficits in reading were nearly five times more likely than were children in the general population to exhibit antisocial behaviours (Rutter, 1974). More recent studies have found elevated rates of specific reading problems and general academic failure in samples of conduct-disordered or delinquent children (Willcutt & Pennington, 2000). Studies also point towards the co-occurrence of attention-deficit/hyperactivity disorder (ADHD) and reading difficulties (RD). Considerable overlap between the two conditions is often found. ADHD and RD are significantly comorbid whether individuals are initially selected for RD (Shaywitz, 2003; Willcutt & Pennington, 2000) or for ADHD. Several studies have found that when both ADHD and specific reading difficulties co-occur in children, these children's deficits on both cognitive and phonological measures are more severe than they are for children who have either one of the two disorders (Hari, Renvall, & Tankskanen, 2001; Wilens, Faraone, & Beiderman, 2004).

A study by Hinshaw (1992) reported a strong correlation between inattention and hyperactivity in younger children exhibiting academic underachievement. In adolescents, the correlation between antisocial behaviour and delinquency was found to be high. Hinshaw (1992) also reported that low socioeconomic status, low intelligence, neuro-developmental delays and language deficits contribute to the presence of emotional or conduct problems in this population. Speech and language difficulties in childhood were reported to be more strongly associated with attention deficits and internalising of problems rather than with antisocial behaviour (Voci, Beitchman, & Wilson, 2006).

Goldston and colleagues (2007) studied psychiatric comorbidity in two groups of 15-year-olds. The first group ( $N = 94$ ) had reading difficulty; the second group ( $N = 94$ ) typically developing adolescents. The study found the adolescents with reading disorder had a greater prevalence of psychiatric comorbidity, such as attention deficit and hyperactivity.

### **1.7.2 Emotional Problems**

A few studies have indicated that children falling within the broad categorisation of “learning disabled” exhibit more symptoms of depression than children without a learning disability (Stringer, 2006). Fisher, Allen, and Kose (1996) studied the relationship between anxiety and problem-solving skills in children with and without learning disability. They found that boys with learning disability reported significantly higher pre-test trait and state anxiety on the State-Trait Anxiety Inventory for Children than did boys without learning disorders, and their perceived state of anxiety escalated over the course of the problem-solving session. Children who met criteria for specific reading disorder did not differ significantly from children without reading difficulties on a measure of neuroticism (Rutter, 1974).

In contrast, another study found that children with reading disorder with comorbid behaviour problems exhibited significantly more anxious/fearful behaviours than control children. Boetsch, Green, and Pennington (1996) compared both clinic-referred and community samples of children, adolescents, and adults with reading disorder to a normal control sample. They found that the children with reading disorder exhibited significantly more internalising symptoms than did the control controls on the parents’ version of the

Child Behavior Checklist (Achenbach, 1991). Reading disorder children also endorsed more symptoms on the Children's Depression Inventory (Palladino, Poli, Masi, & Marcheschi, 2000) but were not significantly different from controls on self-report interview for overanxious disorder.

In a study by Snowling and colleagues (2006), the rate of psychiatric disorder was found to be low in children with speech and language delays; those whose language delays had resolved by five years, five months of age had a good outcome. Those children whose language difficulties persisted through the school years had a raised incidence of attention and social difficulties. The children with attention problems showed a profile of specific expressive language difficulties while children with social difficulties had receptive and expressive language difficulties. Voci and colleagues (2006) followed a community sample of children from the age of 5 to 19. They found that children with language impairments in early childhood were 2.7 times more likely to develop social phobia in adolescence than children without language impairments. The authors concluded that social phobia in adolescence correlates highly with language impairments in childhood.

Several Indian studies have also pointed to the presence of comorbid conditions associated with specific reading disorders. Shenoy and Kapur (1996) noted that 21 out of 88 children with learning disability had a comorbid psychological diagnosis. Kishore et al. (2000) reported that 21 out of 56 children with specific developmental disorders of scholastic skills had a comorbid psychological disorder. John (2001) found that one third of scholastically backward children had a comorbid psychological problem. Of these, 16% had disorder of emotion, 6% had conduct disorder and 12% had mixed disorders of



emotion and conduct. In a retrospective study conducted at the Child and Adolescent Unit of the National Institute of Mental Health and Neurosciences, Bangalore, Muthukumar, Shashikiran and Srinath (1999) found that 79% of children with learning disabilities had comorbid psychological disorders: 32% had internalizing disorders, 28% had externalizing disorders and 19% had other disorders.

### **1.7.3 Social Skills and Self-concept**

Stephanie, Miguel, Steven, and Kavale, (1996) examined the nature of social skill deficits among students with learning disabilities. They found that about 75% of students with learning disabilities manifest social skill deficits that distinguish them from comparison samples. Approximately the same level of group differentiation is found across different raters (teachers, peers, self) and across most dimensions of social competence. They concluded that social skill deficits appear to be an integral part of the learning disability experience but that questions regarding causality remained unanswered.

Huntington and Bender (1993) reviewed the literature from 1984 to 1993 on emotional wellbeing in adolescents with learning disabilities. They concluded that adolescents with learning disabilities have a less positive academic self-concept, experience higher levels of trait anxiety and have a higher prevalence of somatic complaints. Adolescents with learning disabilities also had high rates of depression and alarming rates of suicide.

A number of comorbid conditions in the domains of emotions and behaviour thus co-occur with reading disability. Some studies claim that these conditions do not directly affect the status of the reading disability while others consider further investigation into

the causality and interrelationship between these factors is needed. However, few studies have looked into what happens to these comorbid conditions after the children receive remediation for their reading. Is there no change or some change in reading scores? Answers to questions of this kind would provide clarity on issues related to causality.

Theorists have covered a wide range of factors—biological or otherwise—that in some way causes, contributes, or is related to specific reading disorder. The next section focuses on the intervention for specific reading disorder and reviews some of the existing practices in remediation.

## **1.8 INTERVENTIONS**

In a broad sense, poor readers of all severities have similar reading-related deficits (i.e., difficulties with word recognition, reading fluency and/or reading comprehension). Within this framework, subgroups of poor readers can be identified, such as those with particular deficits in decoding printed words versus those who have specific deficits in comprehending connected text (Das, 2009). Although the neurobiological underpinnings of reading disorder and their interaction with environmental events continue to merit study, the focus is now on widespread implementation of research-validated interventions. The differing accounts of specific reading disorder have led to the development of different treatment approaches.

In the last 30 years, classroom and laboratory-based studies have emphasised the critical role of phonological processing in successful reading acquisition (National Reading Panel, NICHD, 2000). Phonological awareness (PA), the ability to identify and mentally manipulate constituent speech sounds, has been found to predict much of the variance in reading skills, even in kindergarteners who are just learning the alphabetic

principle. Because explicit instruction in speech sound awareness and sound symbol association helps to prevent reading failure (Bradley & Bryant 1983), concentrated research efforts have attempted to identify the functional neuroanatomy of phonological processing (Poppel, 1996). Advances in brain-imaging technology have helped us to better understand the functional neuroanatomy of phonological processing (Eden & Moats, 2002). It is now clear that phonological awareness shares attributes with other perceptual and cognitive skills and is widely distributed across the brain. It has also been established that throughout reading acquisition, phonological awareness and reading itself have a relationship of reciprocal causation (Castles & Coltheart, 2004; Shaywitz et al., 2003).

How the brain accesses phonemes and associates phonemes with visually presented orthography is not clearly understood. Some researchers suggest that the process relies on linguistic processes rather than on speech sound (Shaywitz, 2003), whereas others have argued for a direct link between the ability to process auditory input and the ability to perceive phonemes (Tallal, 1996). These contrasting theories point to divergent research approaches that seek to understand the etiology of reading difficulties and to eventually offer solutions (Eden & Moats, 2002).

Several systematic, cumulative, explicit and sequential approaches allow professionals to teach language structure at many levels. Some of these are classroom-based activities; others are clinically tested methods. Many of them emphasise the importance of multi-sensory engagement of the learner and teach the phonological features of spoken language using motor, visual, auditory and kinaesthetic feedback combined with extensive, controlled practice in word recognition.

The Lindamood-Bell technique addresses the concept of motor theory of speech perception by emphasising oral-motor feedback and detailed instruction in labelling speech sounds. Phono-Graphix, on the other hand, minimises the multi-sensory method of the Orton-Gillingham method. A major criticism of these programmes is that they have been subjected to quasi-scientific efficacy studies only (Eden & Moats, 2002).

Another approach to intervention takes advantage of the technical advances in computer animation and presentation. Earobics and FastForWord are examples of software programmes that tap phonological and auditory processing skills through interactive computer games. FastForWord emerged from a systematic, scientifically based study of the relationship between auditory processing and language (Gaab, Gabrieli, Deutsch, Tallal, & Temple, 2007).

Several studies have used auditory training methods and explored transfer of these methods to reading skill. Two such studies included rapid auditory sequencing training and language training incorporating acoustically modified speech in which rapid spectrotemporal segments were amplitude-enhanced and extended in duration (Tallal et al., 1996). Children participating in the training program FastForWord showed substantial improvements in the rate of acoustic processing, and in speech discrimination and language comprehension, compared with a well-matched control group of children with language impairment who received the same language training, but with natural speech and no auditory sequencing training. Benefits from FastForWord training have also been reported for children with academic difficulties Troier and Whitney (2003) showed greater gains in oral language tasks and tests of phonological awareness, and a greater decline in behavioural problems, following four to eight weeks of training

compared with controls. Hook et al. (2001) found that gains achieved with FastForWord training were similar to those obtained using the Orton- Gillingham reading remediation method.

Temple and colleagues (Temple, 2002; Temple et al., 2003) were the first to report significant improvements in both reading and language scores in dyslexic children who had experienced FastForWord training. In addition to being administered standardised reading tests, children with dyslexia and typical readers received two fMRI scans eight weeks apart while performing a letter-rhyming task. Between scans, children with dyslexia completed the FastForWord language-training program. After the children had received the training, their performance on all measures of oral language and reading showed significant improvement. The control group showed no significant change. Prior to training, the children with dyslexia showed no activation in the temporo-parietal region. After training, fMRI results demonstrated that the children with dyslexia showed increased metabolic activity in left hemisphere temporo-parietal language regions, bringing their brain activation closer to that seen in typical readers. Not all studies have found significant effects following FastForWord training (Cohen et al., 2005) and some have failed to document sustained benefit over time (Hook et al., 2001).

Several studies have explored for the outcome of these remedial programmes on reading and spelling accuracy. In summary, remedial approaches using the phonological awareness methods have been found the most effective in improving reading skills among impaired readers. Berninger and Richards (2008) scanned the brains of 18 children before and after phonological awareness intervention. Before intervention, the children with specific reading disorder differed from normal controls in the connectivity

of the left inferior frontal gyrus and its correlations with the right and the left middle frontal gyrus, the right and the left supplemental motor area, the left precentral gyrus, and the right superior frontal gyrus. The children with specific reading disorder also showed greater connectivity between the left and the right inferior frontal lobe. After a three-week intervention programme, the two groups did not differ in the brain activation pattern. The authors concluded that this change had occurred because the intervention programme had resulted in better connectivity in the brain.

However, several studies have noted that while most children with specific reading disorders benefit from phonological awareness interventions, some children continue to have deficits despite such intervention. In addition, some children do not have phonological deficits to begin with while others have deficits other than phonological awareness, which could influence their performance in the intervention. Other intervention modules may be necessary with these children.

Many children with specific reading disorder show deficits on a range of cognitive measures. On the basis of these findings, theories have been posited regarding the role the brain plays in the process of reading and how deficits can be connected to various areas in the brain. Researchers have found changes in the brain subsequent to intervention (Shaywitz 1999, 2003; Simos et al., 2002; Temple et al., 2003). Anatomical changes have been known to be associated with repeated practice on tasks. But how does one account for such anatomical changes in the brain? Few studies have attempted to provide training for remedy of observed cognitive deficits and fewer still have attempted to look at what happens to these cognitions after phonological awareness training.

Das (2009) suggested an alternative method of understanding the reading difficulties seen in children with specific reading disorder. He proposed the PASS theory to explain the presence of the cognitive, reading and phonological awareness deficits exhibited by children with dyslexia. According to this theory, cognitions can be divided into four components—planning (P), attention-arousal (A), and simultaneous (S) and successive (S) processing (PASS). Phonological awareness, word recall, rapid naming, speech articulation and non-verbal short-term memory are successive processes while similarities, line orientation and visuo-spatial judgment are simultaneous processes. Deficits in these cognitions and in visual attention are found in children with dyslexia. Thus, the reading and cognitive deficits can be explained on the basis of the PASS theory. In 2004, Das and colleagues developed two remedial programmes using the principles of PASS theory. The PASS remedial training programmes named COGENT and PREP are based on the remedial principles of Hebb, Luria, and Vygotsky (Das, 2009).

Cognitive enhancement training (COGENT) was successfully used with a group of 11 disadvantaged Indian children in the age group four to seven years (Das, Hayward, Samantaray, & Panda, 2006). The children were screened for cognitive and academic difficulties and were identified as being at risk of developing reading disorders. After the intervention programme 54% of the children showed gains in all four cognitive processes; the changes were also reflected in their behaviour and motivation.

Hayward, Das, and Janzen (2007) used the COGENT programme in Canada on a group of 17 disadvantaged Grade 3 children at risk of developing reading difficulties. The training programme covered a whole academic year (about 30 hours of instruction) and

each child had three 30-minute sessions each week. Most of the children showed improvement in reading and phonological awareness. The authors accordingly claimed that their neuropsychological programme is effective not only with children with dyslexia but also with children at risk of developing reading difficulties. Similar results were reported for the other training module (PREP) that used the PASS theory to train children with reading disorder. This study appears to be the only one that has developed a neuropsychological training program for use with children with reading difficulties.

The next section examines the nature of cognitive deficits, neuropsychological remediation and the principles underlying the latter in the context of developmental disorders.

### **1.9 PRINCIPLES OF NEUROPSYCHOLOGICAL REMEDIATION**

The central premise of neuropsychological remediation is that intervention will produce some change in a person's functioning that would not occur as well, as quickly or at all on its own (Stuss & Benson, 1986). How a person with cognitive deficits improves and learns to function better is a controversial issue and is often described by one of two disparate modules of recovery. The first is a biological module; the second centres on learning, experience and psychological processes (Yishay & Diller, 1993). The biological models emphasise the pathophysiological events and brain plasticity as the main constraints on functioning and recovery. Learning and adaptation secondarily interact with biological systems in the recovery process. The learning model emphasises the role of experience, practice and the environment in producing functional changes by way of restoration of impaired capacities or substitution of new means of functioning.



The concept of Hebbian learning is an important one in providing a framework for analyzing interactions between the neural and behavioural levels of analysis. Hebb (1949) argued that strengthening of synaptic connections occurs when pre- and post-synaptic neurons are coactive. Two neurons or groups of neurons disconnected by a lesion may become reconnected if they are activated at the same time. Simultaneous activation will take place if both neurons are separately connected to a circuit whose neurons themselves are functionally interconnected. When this net of neurons is activated, the two neurons that are disconnected from each other are simultaneously activated. Several repetitions of this process can lead to these two neurons reconnecting.

The method of cognitive remediation based on the Hebbian principle is generally used for cognitive deficits produced after insult or injury to the brain. However, in the current study, we attempt to use the same principles of cognitive remediation on a developmental disorder. Our understanding of reading as a developmental disorder is that the connections between the target sites are not been completely established during the developmental process. Therefore, instead of facilitating the reconnection of previously linked regions, we hope to be able to facilitate the establishment of new connections through neuropsychological remediation. The basic premise of a neuropsychological remediation programme is that success of the programme depends on the plasticity of the brain. The next section describes brain plasticity and its association with neuropsychological remediation.

### **1.9.1 Neuronal Plasticity and Cognitive Development**

A common claim in the literature from developmental neuropsychology is that the developing brain is plastic. This means that during development, the brain is capable of

reorganising patterns and systems of connections in ways that the mature brain cannot. One important consequence of this early and transient property is that the developing brain is much less vulnerable to the detrimental effects of injury than are the more mature neural systems. Data from studies of paediatric clinical populations generally support this claim. In literature on human developmental neuropsychology, the most common use of the term plasticity relates to the well-documented resilience of young children to the effects of early occurring neural pathology.

A large body of data documents the fact that focal brain injury in childhood results in limited patterns of behavioural and cognitive deficits, which is not the case with similar injury in adulthood. These differential and less devastating outcomes following early injury to the developing brain's capacity is evidence of plastic reorganisation. This capacity for reorganisation declines with maturation. Lenneberg (1967) proposed that the neural systems that mediate language develop according to a maturational blueprint. Different brain regions are genetically pre-specified for particular cognitive functions; under a typical maturational timetable, specific regions become committed to pre-designed functions. This profile of maturation gives rise to the patterns of brain organisation observed in most normally functioning adults. When a developing neural substrate is damaged or altered, alternative patterns of organisation are possible.

Robertson and Murre (1999) claim that brain development and plasticity are complementary but relatively independent systems. Normal development of the brain occurs according to a pre-determined plan that includes both genetic and environmental factors. If the maturational process is disturbed by insult or injury, the system has the capacity to respond flexibly, thus circumventing the deficit. In that sense, the developing

brain is plastic. Plasticity is available (or not available) for a restricted period of early development, and it serves as a means of shielding the developing organism from the potentially harmful effects of injury to the brain. Plasticity is termed as a central feature of normal brain development (Stiles, 2002).

According to developmental neuropsychologists (Stiles, 2002), plasticity of the brain is a process that occurs regardless of whether there is insult or injury to the developing brain. It does not necessarily occur only in response to damage; rather, it is a process that underlies all cognitive development. The process of plasticity operates in both normal development and in development following early injury. Application of the knowledge of the term plasticity is seen in neurochemical systems, cell assemblies and connections and behaviour. Factors such as enriching environments, opportunities to “rewire the circuits” and the age, size and extent of lesion/injury determines the amount and nature of plastic reorganisation that occurs.

Studies by Kolb and Gibbs (1990) suggest that early brain development is dynamic and subject to both endogenous and external effects. Their work shows that brain damage has detrimental effects that are specific to the timing and location of the lesion. However, the effects of early injury can, at least in some cases, be mitigated by the organism’s interaction with the environment. In the case of reading disability, the assumption is that a disruption in the blueprint of the neuronal migration of cells in specific regions causes the deficits noticed (Geschwind & Galaburda, 1985). There is some plastic reorganisation (Shaywitz, 2003), but it does not result in totally rectifying the disability. Hence, changes need to be brought about through external manipulation.

Several questions arise out of these considerations. First, how does one go about producing these changes in cognitive levels? Second, how does one provide strategies that result in stimulation of the circuits in question? Third, what rehabilitation tasks are appropriate? And, fourth, what aspects of cognition are being rehabilitated? Research on cognitive rehabilitation describes the strategies used to help enhance deficit cognitions acquired after insult or injury to the brain. However, we propose that such strategies can be extended for use with cognitive disorders brought about by developmental processes. The following section describes some of the rehabilitation strategies used to enhance acquired cognitive deficits. The remediation module used in the present study employs similar strategies to help address deficit cognitions in specific reading disorder.

## **1.9.2 Rehabilitation Strategies**

Rehabilitation strategies generally fall into the categories of restorative or compensatory interventions. Cognitive rehabilitation divides along two strategies: process-specific cognitive rehabilitation and functional skills training. The process-specific rehabilitation is largely aimed at enhancing attention, memory and executive functions.

### **1.9.2.1 Attention**

Adequate attention is critical for many types of learning. Attention consists of a number of different sub-systems, such as selective, sustained and spatial attention. Attentional deficits are important in themselves in terms of the direct effects they have on contemporary behaviour and not just in terms of their effects on long-term learning. A relationship exists between attentional and executive processes (Gazzaniga, Ivry, &

Mangun, 1998; Robertson & Murre, 1999). Both types of processes are, to a large extent, frontal lobe functions.

Intervention tasks for attention can be classified into non-specific attentional training and training of specific attentional processes, such as sustained, selective and spatial attention. Tasks used include computer-based vigilance tasks, choice-reaction tasks, tasks based on go/no-go principles, cancellation tasks, serial subtraction, Stroop, number-calculation, digit-span, number comparison, and the like.

Evidence points to the efficacy of enhancing attention subsequent to training (Sholberg & Raskin, 1996). Mateer (2000) reported that rehabilitation programmes targeting attention need to include generalization activities (such as cooking, money management, driving) for the effects of the training to generalise to daily activities. Electrophysiological studies (Sholberg & Raskin, 1996) reported P300 changes subsequent to a generalized training programme suggesting the possibility of attention enhancement through a well drawn rehabilitation programme.

### **1.9.2.2 Executive functions intervention**

Individuals with executive function impairments display problems in starting and stopping and making mental and behavioural shifts relative to attention and awareness of self and others. Component processes hypothesised to support executive control include activation/drive systems, inhibitory control, working memory, interference control, prospective memory and self-monitoring/regulation (Sholberg & Raskin, 1996). Different anatomical regions within the frontal lobes are responsible for the intact functioning of these components of executive functioning.

Damage to the frontal lobes can present with one or more executive function deficits. Management of executive dysfunction is typically brought about in one of three ways:

1. *Environmental manipulations*, such as altering demands on the individual, simplifying tasks, eliminating tasks, and allowing longer time frames.
2. *Compensatory approaches*, such as using a memory notebook, increasing the amount of time employed on a task, increasing self-awareness and teaching metacognitive strategies.
3. *Direct interventions*, involving the use of procedures that have as a goal improving or restoring some underlying ability or cognitive capacity.

Most of these strategies have been used with individuals with insult or injury to or lesions in the brain. Several researchers, however, oppose the idea of using these same strategies directly for deficits arising during the developmental process (Stiles, 2002). The neural network approach considers the Hebbian principle that “cells that fire together wire together” (Robertson & Murre, 1999). This understanding provides sufficient flexibility for the approach to be used with both acquired and developmental conditions.

Sholberg and Mateer (1989) applied what they called a “process-oriented approach” to intervention. The basic tenet of their approach provided a solid understanding of the specific cognitive areas involved and a detailed analysis of the nature of impairments in that area. The researchers followed this work by providing hierarchical training exercises designed to provide structured opportunities to practise and thereby strengthen particular cognitive skills. Repetition is believed to be critical to the re-automatisation of such abilities. The current study used tasks based on the principle of

repetition of tasks that can be hierarchically placed and have known association with functioning of the brain areas of concern in specific reading disorder.

### **1.10 SPECIFIC READING DISORDER IN THE INDIAN CONTEXT**

India is the seventh largest country in the world in terms of geographical area, and has a population of about 1.2 billion people. People from different states in India speak different languages. There are 16 official languages in India. Each state has its own official language. In addition to these are the national language (Hindi) and English, both important languages that the majority of Indian people use for communication (Ministry of Information and Broadcasting, 2008).

India's education system reflects the influence of language on the learning process. The medium of instruction in the school can be English or the regional language. Children studying in schools learn all subjects in the language chosen as the medium of instruction. They also learn one or two languages other than the medium of instruction as core subjects in their curriculum. Assessment of language and its processes therefore is difficult to develop and standardise.

#### **1.10.1 The School System in India**

Most Indians are exposed to and can speak more than one language. English is not the language primarily spoken in all homes, which means that many children are not formally exposed to it until they enter school. Being exposed to more than one language during the formative years influences the development of reading in Indian children. Researchers working in the field of language development and typical development of reading are therefore sensitive to the influence of multiple languages in these children.

In addition to the influence of the language used, other variations are seen in India's school system (Kapur, 2008). Urban and rural schools fall under the state syllabus of education or the central syllabus of education. The state syllabus is followed to a large extent in the rural regions and often has the regional language as the medium of instruction. In urban settings, other streams of education run alongside the state syllabus. These include the Indian Council of School Education (ICSE) and the Central Board of Secondary Education (CBSE), both of which come under the central syllabus and use English as their medium of instruction. The state syllabus is relatively easier programme of study than the central system and is the one most adopted by schools run by a state government. The more difficult central syllabus is mostly adopted by privately or centrally funded schools (Kapur, 2008). Children from the low socioeconomic status and from rural regions most often go to government-run schools. Most urban children attend aided or private schools that follow the state, ICSE or CBSE syllabuses.

### **1.10.2 Prevalence of Reading Disorder in India**

Reading represents the means by which much of the information presented in school is learned, and is often implicated poor academic performance and, from there, school failure (Thapa, 2008). Reasons for failure include, among others, presence of learning disorders. About 80% of children diagnosed with learning disorder have specific reading disorder (Karanth, 2008).

Epidemiological studies in India in the field of learning disorders—and specifically in reading disorder—have gained importance only during the last decade (Karanth, 2003). Suresh and Sebastian (2003) found a large prevalence of specific reading disorder in rural areas. Yadav and Agarwal (2008) estimate the prevalence of the disorder at



2.25%, with higher prevalence for boys than girls. However, estimating the exact prevalence in India is compounded by several factors, such as bilingualism/multilingualism, poor awareness by teachers, large number of children per class and unavailability of adequate tools to evaluate children with reading disorder (Karanth, 2008; Yadav & Agarwal, 2008).

In their study, Tripathi and Kar (2008) evaluated the prevalence rates of learning disorders in schools in and around Allahabad, a city in the northern part of India. They found a high prevalence of reading-related problems in Classes 2–5, with the prevalence diminishing across Classes 6–8. The authors found that specific problems in reading, such as letter-sound omissions, substitution, reversals, difficulties in fluency, and reading the same line again were high across all classes. They also found writing difficulties across all class levels. Tripathi and Kar concluded that the high prevalence of writing difficulties could be explained by the high emphasis on writing skills in the school curriculum.

Present understanding of reading disorder in India depends on literature from other English-speaking countries. Western assessment practices and instructional materials and intervention methods are strongly influential (Verma, 2008). Most tests and screening tools used to identify children with specific reading disorder are either tools developed in the West or are adaptations to suit Indian conditions. Some indigenous tools such as the NIMHANS SLD Index are available for use in English. Chapter 3 provides a description of this tool. Tools sensitive to the local languages, such as the Reading Acquisition Profile in Kannada (RAP-K), developed by Prema (1998), are also in use. Shankarnarayan (2003) used letter identification, word recognition and reading texts

along with Western tests such as Rhyming, Torgesen Elision, Rapid Automatised Naming, Rapid Alternating Stimulus, Short-term Memory for Digits, Conservation, Handedness, and Vocabulary. She found that the best predictors of reading ability for the Indian sample were speed of naming letters, vocabulary, and phonological awareness.

Rozario (2003) prepared an informal reading inventory by carefully selecting graded reading passages and identifying specific reading errors. She used a similar procedure for assessing spelling and writing disorders. Rozario (2003) recommended that each individual's strengths and weaknesses must be identified in order to develop a highly individualised profile of that person's cognitive and personality styles (Verma, 2008).

### **1.10.3 Phonological Awareness in the Indian Context**

Appreciation of the relationship between phonological awareness and early reading has its origin in the English-speaking nations. However, this awareness and understanding spread to both European nations and other non-English speaking nations. Although the sequence of phonological awareness development is similar across languages, the sub-syllabic units of which children become aware generally differ from one language to the next (Gowswami, 1999; Karanth, 2008). Researchers generally agree that the relationship between different phonological awareness and the ability to read words holds for languages such as Spanish, German, English and French, but does not hold good for non-alphabetic scripts (Harris & Hatano, 1990). Harris and Hatano (1990) and Gowswami (1999) agreed that more cross-cultural research would be required before firm conclusions could be drawn, a claim that remains relevant today.

Eastern scripts, such as those of China, Japan and India, do not support a strong relationship between phonological awareness and early reading skills (Karanth, 2008).

The Indian languages are written in a script classified as an alphasyllabary—a syllabary incorporating alphabetic principles in which the basic unit of writing the “akshara” is a syllable. For example the Kannada (one of the alphabetic scripts in India) word “*pustaka*” meaning book comprises of three letters representing the syllables /pu/ /sta/ and /ka/, each letter representing one or more consonants and a vowel. Therefore studies have explored for the role of phonological awareness in the acquisition of reading skills in children who study in the local/regional language versus those who learn in English at school in India. (Karanth, 2008)

Prakash (2003), Prakash and Rekha (1992), Prakash, Rekha, Nigam, and Karanth (1993), and Prema and Karanth (2003) have together established that phonological awareness is neither as evident nor as crucial to successful reading in Indian writing systems. The researchers found that children learning to read alphasyllabaries and adults who learned only in one Indian language (Kannada or Hindi) performed well in rhyme recognition and syllable deletion tasks but did not perform well on segmentation tasks. In contrast, those who studied in both English and one Indian language (Kannada or Hindi) were able to carry out the phoneme segmentation tasks. Prakash and Rekha (1992) found that children from Kannada medium school showed a spurt in their performance on phoneme awareness tasks such as phoneme isolation and deletion after being introduced to English language in the fourth grade. Karanth (2008) concluded that the kinds of connections beginning readers make with phonology and orthography depend on the orthography of the language being learnt.

Sharma (2000) investigated the language skills of 23 (7- to 15-year-old) Hindi-speaking children with reading disorder. None of the children was known to have oral

language deficits. All were assessed on the Hindi version of the Linguistic Profile Test (LPT) (Karanth, 1984; Sharma, 1995), which evaluates language at phonological, syntactic and semantic levels. The study indicated that the children with reading disorder have a lower language age (below six years) than those without. The deficits of the older children were more pronounced, especially relative to the more complex aspects of language abilities. A similar finding was reported for 21 Malayalam-speaking children, (6 to 15 years of age. (Malayalam is another Indian language.) All 21 children had greater language deficits than phonological deficits. The older children showed a higher incidence of deficits than did the younger children.

#### **1.10.4 Interventions for Specific Reading Disorder in India**

In India, when children with specific reading disorder are identified, they either, depending on the severity of the reading difficulty, attend a special school or regular school while attending remedial sessions for a few hours a day. Several remedial centres use individual educational programmes (IEPs) based on the assessment profile of the child. Only a few educational and clinical psychologists develop and/or use remedial programmes. Carefully controlled interventions studies for specific reading disorder for children in India are scarce, and their approaches and outcomes vary. This section presents three such studies.

Rozario (2003) described a remedial training programme consisting of training on phonics, sight-word reading and language skills. Srikanth and Karanth (2003) used a remedial programme based on the Aston Teaching Programme. With both these studies, cases were assessed and remedial work was done that kept in mind individual error patterns and areas of difficulty. The remediation focused on auditory visual channel,

specific spelling rules and cues, comprehension skills, oral expression and visuo-motor perceptual aspects. The authors concluded that a complete remedial programme should aim at both reading and spoken language proficiency.

Padegar and Saranth (2008) assessed three children in the age range of 7 to 11 years who had been referred to the Maharashtra Dyslexia Association resource centre for remediation of severe reading disorder. All three children had above-average intelligence. They were assessed on word attack and word identification subtests before and after intervention. The intervention programme used was the PASS Reading Enhancement Programme or PREP (Dass, Naglieri, & Kirby, 1994). This programme for primary school-children aims to improve information-processing strategies, specifically the simultaneous and successive processing that underlies reading, without direct teaching of phonological skills such as phoneme blending and segmentation. The authors compared the assessment profile of these three children with three other children with specific reading disorder who received regular remedial training consisting of training on phonics, sight word reading and whole language approach. Both interventions were given for 24 sessions. The control group received only remedial training while the PREP group received PREP as well as remedial training once a week. Results showed improvements for both groups, but the PREP group showed an increase in their word identification and word attack skills after intervention.

#### **1.10.5 Issues Pertinent to the Indian Context**

The review of children with specific reading disorder in the Indian context highlights several important issues. First, the education system and the sociocultural differences pose a challenge to professionals working in the field. Second, the influence of many

languages in the education system creates particular difficulty not only for children with specific reading disorder but also for those interested in assessing and remediating the disorder. Third, because Indian languages differ in structure from that for English, inferences drawn on Western populations may not be readily applicable to the Indian population. Finally, the use of Western tools of assessment and remedial training may not be effective for all groups of children with reading disorder across the country. While certain tools and remedial procedures might still be relevant for children from English-medium schools, their relevance for the vernacular medium of schools is questionable.

Intervention for specific reading disorder poses another challenge in that intervention programmes used effectively with English-speaking children may not be suitable for multilingual Indian children. In addition, the demands that the school places on children in India may be very different from the demands placed on children in other countries. Therefore, if an intervention programme is to be effective in the Indian system, it must consider the demands placed by the education system on the child and the influences of his or her environment. In short, a programme found to be effective in another country will not necessarily yield the same result in India.

The current study examined the effectiveness of two interventions (a phonological-based intervention and a neuropsychological-cognitive-based intervention) in meeting the needs of children in the Indian education system. The phonologically based intervention has proven effective in meeting the needs of Australian and New Zealand monolingual English-speaking children (Gillon, 2000; Gillon & Dodd, 1997), and its effectiveness in another educational environmental context is explored in this thesis. The second

intervention was developed for this study. The next session explores the rationale for employing and developing these interventions.

### **1.11 FRAMEWORK FOR THE PRESENT STUDY**

Cognitive deficits have been found in children and adults with specific reading disorder. These deficits include phonological processing, sensory visual processing, visual speed discrimination thresholds, implicit learning, rapid acoustic processing, auditory processing, rapid naming and automatised phases of motor skills acquisition. Some of these deficits are grouped broadly under phonological processing deficit, which is further classified into phonological awareness, storage and retrieval and rapid naming. In addition, deficits in attention, scanning, word-finding problems and working memory have been associated with reading disorder (Lovett & Steinbach, 1997; Price, 2000; Swanson, 1999). Working memory is known to interact with higher order reading functions such as lexical, semantic and syntactic processes. Attention is known to interact with higher order and lower order reading functions, such as visual perception and phoneme-grapheme conversion (Price, 2000).

Comparisons between normal readers and disabled readers have thrown light on the anatomical correlates of reading. The regions involved include the occipito-temporal region for line orientation and visual features of words. Posterior inferior and medial temporal lobe is responsible for processing at the lexical level of language comprehension. Temporal-parietal junction is responsible for phonological processing; superior temporal gyrus for phonological awareness; angular gyrus for orthography and sub-lexical processing; anterior cingulate cortex responsible for response conflict resolution; inferior-frontal gyrus for working memory and attention tasks; and cerebellum

for automatization of motor skill acquisition (Habib, 2000; Howard, Howard, Japikse, & Eden, 2006; Nicolson, Fawcett, & Dean, 2001; Shaywitz, 2003; Shaywitz & Shaywitz, 2005).

There is considerable overlap between the cognitive deficits noticed and the anatomical regions implicated in specific reading disorder. According to Price (2001), “reading is a secondary system which is not associated with areas specific to reading but which rather recruits brain areas primarily subscribing other functions.” The current study hypothesises that the anatomical regions associated with reading also sub-serve other cognitive functions. Dysfunction seen in reading suggests dysfunctions in those circuit(s) and thus points towards a multiple-symptom profile. Addressing only the phonological processing deficits would therefore result in only partial remediation of deficits.

Remedial studies focusing on specific reading difficulty have found structural changes in the brain following remediation (Shaywitz & Shaywitz, 2005; Tallal, 1980) that correlate with improvement seen in some aspects of reading, especially phonological awareness, non-word reading and/or successive and simultaneous stimuli. The other (cognitive) deficits have not been addressed in these studies. Despite many studies pointing towards the presence of cognitive dysfunctions, few have attempted to remediate them, and fewer still have attempted to remediate all of the deficits.

Interventions focusing on phonological awareness and processing have gained much popularity over the years. Castles and Coltheart (2004) reviewed studies exploring effects of intervention using phonological awareness intervention. Their review pointed to two important aspects. First, despite claims of improvement in reading after



phonological processing intervention, the design of the studies did not account for establishing a causal relationship between reading disorder and phonological awareness abilities. Second, some studies point to the presence of poor responders to phonological processing interventions while others show benefits from the same intervention (Schnnider, 1999). Despite the presence of studies pointing to presence of cognitive deficits, few studies have focused on providing therapy for the cognitive deficits evident among disabled readers.

In the present study it was hypothesised that the presence of both cognitive and phonological awareness deficits would explain the reading disorder observed in the participants. Because several cognitive processes are involved here, the disorder would appear to be multi-faceted, with phonological awareness featuring as only one aspect of this complex picture. Addressing phonological awareness alone would result in partial remediation only, thus explaining why some children continue to show deficits despite undergoing remediation for phonological awareness. It is also proposed that these cognitive deficits interfere in various domains of functioning, in addition to reading, if left untreated. Hence, remediation of all the cognitive deficits is required to produce improvement across all domains.

Several studies show a number of clinical conditions, such as emotional and behavioural disorders (Hinshaw, 1992; Willcutt & Pennington, 2000), associated with reading disability. Few studies, if any, however, have looked at what happens to these comorbid conditions subsequent to remediation for reading. It is therefore hypothesised that improvement in reading will be associated with improvement in secondary comorbidities.

The literature suggests that several issues with regard to reading disability and its management have yet to be addressed. In the Indian education system, all children are assessed on the basis of written tests or examinations conducted every term. Emphasis in the examinations/tests is placed on writing and spelling abilities. Each child obtains marks out of a total 20 to 25 for tests and 100 for examinations. A cumulative record is presented to the parents to help them assess the performance of their child in school. Children are not routinely assessed for presence of reading disorder. Instead, they are identified as children scoring below the cut-off scores required to pass the grade or term.

Some children who consistently underperform are referred to psychologists and/or remedial centres for assessment and remedial training. Very few remedial centres around the country, if any, offer phonological awareness training for reading disorder. In addition, those children with reading disorder face increasing demands from their parents and teachers. We therefore considered there is a strong need to identify for children studying in the Indian education system a remedial programme that does not focus solely on reading but also addresses the fact that the Indian system also emphasises writing and spelling.

Phonological awareness remedial programmes are used to help children with reading disorder overcome their reading difficulties. However, in India, this approach is not used as a matter-of-course treatment. Establishing the efficacy of a phonological awareness remedial programme in India would help strengthen the relationship between reading accuracy and phonological awareness.

The current study aimed to address these issues by developing a neuropsychological remediation programme covering a wide range of cognitive deficits

known to be associated with reading disability and comparing it with a remediation based on phonological awareness in a group of children 10 to 12 years of age. Through neuropsychological remediation based on Luria's "functional reorganization" and current understanding of neural plasticity, an attempt was made to reorganise the surviving neural circuits to achieve the given behaviour in a different way.

Repeated practice of tasks arranged in a hierarchical fashion leads to automaticity in cognitive processes (Schneider, 2003; Schneider & Shiffrin, 1979). The automatising of these cognitions may enhance the neural plasticity within the target areas. We propose that the plasticity results in enhanced reading because reading is a secondary function within the targeted cognitions. Processes in reading that require effort because of improper functional connectivity lead to problems in comprehension and speed of reading. It is therefore proposed that, as a result of neuropsychological remediation, these processes become automatic, leading to increases in reading comprehension and speed.

In addition, we considered that assessment of associated clinical comorbidities before and after remediation of reading could throw light on the relationship between reading and other clinical features. Moreover, comparing two forms of treatment—phonological awareness therapy (Gillon & Dodd, 1997) and neuropsychological remediation (developed during this study)—could help to ascertain the efficacy of one form of treatment over another for reading disability.

Clinical knowledge and existing literature indicate that phonological processing ability is a key component of reading ability and reading disorder. Providing specific remedial training to improve phonological awareness could result not only in improved phonological processing abilities but also in better/improved reading skills. Recent

literature has shown changes in brain activation patterns subsequent to remedial training in phonological awareness training. However, few studies, if any, have explored deficit cognitions in this population and their relationship to phonological awareness training. The current study aimed to document the presence of cognitive deficits (in addition to reading deficits) in children with reading disorder. The study also examined changes in the deficit pattern in response to the remedial training.

The current study furthermore hypothesised that, regardless of the nature of the training, children with reading disorder would show improvement in their reading, phonological processing ability and neuropsychological functioning after intervention. The effectiveness of phonological awareness intervention versus neuropsychological intervention on reading was explored by comparing the changes in the two treatment groups after intervention. Because there are few neuropsychological awareness remedial programmes available for use with reading disorder, a remedial package based on Luria's principles of "functional reorganization" was, as noted above, developed as part of this study.

The main study thus focused on three aims:

1. Developing a neuropsychological remediation programme to improve reading disability;
2. Comparing the efficacy of the neuropsychological remediation programme with phonological awareness intervention for children being educated within the education system of India; and
3. Examining changes after intervention (either phonological awareness or neuropsychological) on phonological awareness abilities and cognitive abilities.

## 1.12 HYPOTHESES

1. Phonological awareness intervention will improve phonological awareness, word decoding and reading ability.
2. Phonological awareness intervention will not improve cognitive functions not targeted in the intervention programme.
3. The neuropsychological intervention programme will improve reading, attention, executive functions, verbal and visual learning and memory.
4. The neuropsychological intervention programme will not improve phonological awareness skills not targeted during the intervention.
5. The interventions will bring about changes in the emotions and self-image of the children with reading disorder.

In order to establish cognitive deficits in children with reading difficulty and to explore the effect of intervention on cognitive, reading and phonological deficits, a pilot study involving monolingual English-speaking children in New Zealand was conducted. The next chapter details the study, outlines its rationale, and describes its findings.

## **CHAPTER II: AN EXPLORATORY STUDY OF THE RELATIONSHIP BETWEEN PHONOLOGICAL AWARENESS INTERVENTION AND NEUROPSYCHOLOGICAL FUNCTIONING IN CHILDREN WITH SPECIFIC READING DISORDER**

### **2.1 INTRODUCTION**

It is widely accepted that a phonological processing deficit is a core contributor to reading disorder (Gillon, 2000; Shaywitz & Shaywitz, 2005). Children with specific reading disorder have an impairment in the representation, storage and/or retrieval of speech sounds (Ramus et al., 2003; Shaywitz et al., 2002). At a neurological level, it is assumed that the origin of the disorder is a congenital dysfunction of the left-hemisphere perisylvian brain areas underlying phonological representations (Ramus et al., 2003). Support for the phonological deficit theory comes from evidence that children with reading disorder perform particularly poorly in an aspect of phonological processing, namely phonological awareness (i.e., conscious awareness of the sound structure of spoken words) (Gillon & Dodd, 1994). In addition, children with reading disorder exhibit phonological processing deficits in at least two other areas: rapid naming (of pictures, colours, digits or letters) and verbal short-term memory, neither of which involves reading (Ramus et al., 2003; M. Snowling, Bishop, & Stothard, 2000).

The role of phonological processing abilities in word-decoding development has been well established (Bradley & Bryant, 1983). Remediating phonological deficits or significantly enhancing children's phonological awareness ability can lead to significant improvements in both reading accuracy and reading comprehension for poor readers (Gillon & Dodd, 1995, 1997). Support for phonologically based theories of reading

disorder is also provided through functional imaging studies. After phonological-based intervention, changes in brain functioning of children with reading disorder during reading activities have been reported (Shaywitz et al., 2002; Simos et al., 2002; Torgesen et al., 2001). Aylward et al. (2003) assessed the effects of instruction comprising phoneme mapping and morpheme mapping tasks on functional magnetic resonance imaging in children with reading disorder. They found that the instruction was associated with improved reading scores and increased brain activation in areas that were under-activated before intervention.

Despite their popularity, the phonologically based intervention methods have not addressed all aspects of reading disorder. Several studies have shown that while some aspects of reading improve with intervention, other aspects, such as speed of reading and reading comprehension, tend to persist or are difficult to treat (Torgesen et al., 2001). Simos et al. (2002) examined changes in the spatial-temporal brain regions in a group of children with reading disorder using Phono-Graphix and Lindamood-Bell (1987) methods of instruction. They noted that the behavioural changes did not include improved reading fluency, and that the angular gyrus is associated with phonological decoding. However, because most imaging studies report changes in the temporal-parietal region, they speculated that including activities that tap functions of other regions of the brain associated with reading could lead to improvements in speed and fluency of reading.

Long-term follow-up studies have shown that although children with reading disorder improve in phonological processing and word-decoding abilities, some of them fail to show gains in rate and fluency of reading (Schneider, Ennemoser, Roth, & Vise,

1997). Therefore, in these children, improved phonological processing abilities do not transfer to reading fluency. The present study attempted to identify if neuropsychological factors restricted some children with reading disorder from benefiting from phonological awareness intervention.

Deficits in attention, scanning and working memory have been associated with children with reading disorder (Lovett & Steinbach, 1997; Price, 2000). Deficits involving areas such as the left pre-frontal cortex involved in executive functions, attention, scanning and aspects of motor programming (Brosnan et al., 2002) and cerebellum and subcortical structures (Heyder, Suchan, & Daum, 2004) are implicated in this population. Cognitive functions such as attention and executive functions are known to play a supportive role in the reading process. Anatomical studies indicate that the involvement of the superior temporal areas (Brodmann area 37) and the posterior parietal lobe (BA 39 and 40) in the left hemisphere differ between reading disorder groups and good readers (Brunswick, McCrory, Price, Frith, & Frith, 1999; Ramus, 2003; Shaywitz, 2003; Simos et al., 2002).

The under-activation seen in imaging studies of these anatomical regions suggests phonological awareness deficits in this group. In recent years, several studies have pointed towards the presence of executive function deficits in this population (Protopapas, Achroniti, & Skaloumbakas, 2007). The presence of executive function deficits in children with reading difficulty may suggest possible involvement of bilateral prefrontal cortex, basal ganglia and cerebellum. The phonological awareness deficit alone might not be enough to explain the executive function deficits seen in this population. It



is hypothesised that the executive functions are an important aspect of the cognitive functioning that contributes to reading.

Phonological awareness intervention studies have typically explored outcomes related to phonological awareness, reading and spelling. This approach has restricted our knowledge of how other neuropsychological functions may influence phonological awareness intervention outcomes or may be altered as a result of the intervention. This study aimed to identify the presence of neuropsychological deficits in a small group of children with reading disorder. Changes in the neuropsychological functions after phonological awareness intervention were evaluated. The neuropsychological deficits present in a small group of children with reading disorder were then compared with this presence in a group of good readers.

It was hypothesised that before the intervention, deficits would be noticed on neuropsychological tests of attention, executive function, verbal memory and visual-spatial abilities. In addition, it was expected that, after intervention, differences on the verbal memory and visual-spatial abilities would show improvement along with improvements in reading and phonological measures. It was anticipated, however, that other associated neuropsychological functions not addressed in the intervention, such as executive functions, would still be present post-intervention.

## **2.2 METHOD**

### **2.2.1 Participants**

#### **2.2.1.1 Children with reading disorder**

The reading disorder (RD) group consisted of four children attending a New Zealand university clinic specialising in treatment of children with phonological processing difficulties. Children with reading and spelling difficulties are referred to this clinic by teachers, speech-language therapists and other professionals, and are assessed by speech-language therapists on a battery of phonological processing, language, reading and spelling tasks prior to intervention.

For the purpose of this study, children in the age range of 8 to 15 years with reading disability who were waiting to commence phonological processing intervention were considered. Children without sensory, physical, neurological or emotional disorders, whose parents had provided consent, were included. The four children who met these criteria spoke English as their only language, had no history of services from a speech-language therapist and attended schools in mid-socioeconomic areas (as determined by the New Zealand Ministry of Education's school ranking system).

Receptive vocabulary performance was measured using the Peabody Picture Vocabulary Test – PPVT- III (Dunn & Dunn, 1997) during the pre-treatment assessment. Their performance (shown in Table 1) revealed that they were in the average to above-average range of vocabulary proficiency.

The Neale Analysis of Reading Ability-Revised or NARA (Neale, 1988) was used to measure participants' reading performance. This test consists of a series of graded

passages/stories that the child reads aloud. This process yields a reading accuracy score. The child is then required to answer questions regarding the story, yielding a reading comprehension score. As shown in Table 2.1, all four children demonstrated severe reading accuracy difficulties.

### **2.2.1.2 Good readers (NRD group)**

Four good readers (the NRD group) were included in the study so that their neuropsychological profiles could be compared with those of the RD children. Like the RD children, the NRD group ranged in age from 7 to 10 and attended a school in a mid-socioeconomic neighbourhood. A group of children deemed good readers by their class teachers on the basis of curriculum assessments and whose parents had also given their permission for the children to participate in the study were referred by their teacher to the study. The four children selected from this group were selected on the basis of their reading accuracy performance on the Neale Analysis of Reading Ability-Revised (Neale, 1988). Their reading accuracy scores ranged between the 60th and 85th percentiles (see Table 2.1).

### **2.2.2 Neuropsychological Assessment**

All participants were individually assessed in a quiet environment by the researcher, the week before the phonological awareness intervention. They were reassessed on all measures in the week immediately following the intervention, that is, 11 weeks after the initial assessment. Each assessment took an average of two hours and was conducted in one or two sessions. Children were provided with adequate breaks during each session. The assessment battery was subdivided into tests for executive functions, visual learning

and memory and visuo-spatial learning and memory. The neuropsychological assessment was carried out in soundproof rooms by the researcher. Each session was videotaped.

*Table 2.1: Demographic details and reading scores of the RD and NRD groups before intervention*

	<i>Age (years)</i>	<i>Gender</i>	<i>YOS</i>	<i>PPVT</i>	<i>RA*</i>	<i>RC*</i>
Poor readers						
RW	8	M	3	93	10	7
BA	9	F	5	115	1	7
DK	13	M	8	93	9	25
JC	14	M	9	106	3	11
Good readers						
DW	7	M	3	#	83	84
JF	9	M	5	#	66	84
JS	9	M	5	#	78	74
KB	10	F	6	#	72	70

*Notes:* YOS = year of schooling; PPVT = Peabody Picture Vocabulary Test (Dunn & Dunn, 1997) reported as standard scores; RA = Reading Accuracy; RC = Reading Comprehension

\*Reading accuracy and comprehension percentile rankings from the Neale Analysis of Reading Ability Revised (Neale, 1988).

# Not assessed.

### **2.2.2.1 Tests of executive functions**

#### *2.2.2.1.1 The Corsi Block Tapping Test (Corsi, 1972)*

This test can be used with people six years of age and over as a nonverbal, visuo-spatial working memory test. The apparatus consists of a series of 10 blocks arranged irregularly

on a 23x3x28cm board (9x3x11in.). The blocks are tapped by an examiner in randomised sequences of increasing length. Immediately after each tapped sequence, the subject attempts to reproduce it, progressing until no longer accurate on both trials of a given sequence or until the end of the series. The test consists of both a forward and a backward series. Each correct response has a score of one. The total number of correct responses in each series yields a forward span and a backward span score. In addition, a total score combining both forward and backward scores can be obtained. In both series, the scores range from 0–16.

#### *2.2.2.1.2 The Digit Span Test (Wechsler, 2000)*

This is a subtest of the Wechsler Intelligence Scale for Children (3rd edition) (WISC-III). The child is asked to listen attentively while a string of numbers (two digit–eight digit long) is read at an even pace. After the digits are read out, the child has to repeat them in the same order (in digit forward) and in reverse order (in digit backward). The score is the largest digit correctly recalled in either of the series. Digit Span is a reliable test ( $r = 0.90$ ) with reliability coefficients ranging from 0.84 to 0.93 for all age groups (Sattler, 2001). The test correlates with Letter-Number-Sequencing ( $r = 0.57$ ) and Arithmetic ( $r = 0.52$ ). Comparing the test with the WISC IQ scales reveals that the subtest correlates moderately with Full Scale ( $r = 0.520$ ) AND Verbal Scale ( $r = 0.51$ ) while for Performance Scale the correlation is low ( $r = 0.47$ ). The subtest contributes substantially to the working memory index and is suitable for all age groups.

#### *2.2.2.1.3 The Stroop Colour-Word Test (Golden, 1978)*

This test measures selective attention and cognitive flexibility. There are three components to this task. First, the individual is asked to name a series of colour words

(word list). Second, the individual is asked to name the colour of a bar (colour list) of Xs (e.g., XXX in red, blue, or green ink). The final task is the colour–word list. Here, the individual is shown the names of colours printed in conflicting ink colours (e.g., the word “blue” in red ink) and is asked to name the colour of the ink rather than read the word. The total number correctly read in 45 seconds for each list forms the score. The Stroop Colour-Word Test has satisfactory reliability (Lezak, 1995).

#### *2.2.2.1.4 The Controlled Word Association Test (COWA) (Benton & Hamsher, 1989)*

This test is a measure of phonemic fluency and requires individuals to generate, in one minute, words beginning with a specific letter. (The letters F, A and S were used in the present study.) Participants are instructed that proper nouns and multiple words using the same stem with a different suffix (e.g., friend, friends, friendly) are not acceptable. The total number of words generated for each letter and average of three trials form the score. Test–retest reliability ranges between 0.70 and 0.71. The test loads on a factor called “abstract mental loading”, which includes other tests such as digit span and mental calculation.

#### *2.2.2.1.5 The Trail-making Test (Lezak, 1995)*

The test has two forms, Form A and Form B. It is a subtest of the Halstead Reitan Neuropsychological Battery. In both forms, the child is required to make a connection by drawing pencilled lines between 25 encircled numbers arranged randomly on a sheet of paper. The numbers have to be connected in order in Form A. In Form B, the sheet of paper contains encircled numbers and letters presented randomly. The numbers and letters have to be connected in an alternating order. The time taken, in seconds, to complete the task is taken as the score for each trail. Longer time taken on this test

reflects difficulties in visual scanning (Form A) and in set-shifting ability (form B). The test has variable reliability, ranging from 0.60 to 0.94. Test–retest reliability for Trail A is reported to be 0.64 while for Trail B it is reported to be 0.78.(D'Elia, Satz, Uchiyama, & White, 1996)

### **2.2.2.2 Test of verbal learning and memory**

#### *2.2.2.2.1 The Wide Range Assessment of Memory and Learning ( WRAML) (Adams & Sheslow, 1990)*

Only the verbal learning subtest from this test was used. This subtest assesses verbal learning and memory. The children’s version can be given to individuals aged 5 to 16. The child is asked to learn and recall 13 words (for seven- and eight-year-olds) or 16 words (for older children). The list is presented over four times, and on each presentation the child is assessed for immediate recall. A delayed recall is noted after 20 minutes. The total number of words learned across the four trials and the numbers of words recalled after 20 minutes are scored.

### **2.2.2.3 Test of Visual Learning and Memory**

#### *2.2.2.3.1 The Rey-Osterrieth Complex Figure Test ( CFT), Form A (Meyers & Meyers, 1995)*

This test assesses visuo-spatial constructional ability and visual memory. The measures of performance include a copy score that reflects the accuracy of the original copy and is a measure of visuo-constructional ability, and immediate or 5-minute and 30-minute delayed recall scores, which assess amount of information retained over time. Taylor’s method of scoring (Lezak, 1995) with a total possible score of 36 based on the presence and accuracy of the 18 units of the CFT was used. The test has good inter-scorer



reliability ( $r = 0.91-0.98$ ); test-retest reliability ranges from 0.60 to 0.76. Both immediate and delayed recall scores have a strong visual memory component as well as a visuo-spatial component.

### **2.3 PHONOLOGICAL AWARENESS INTERVENTION**

The intervention implemented was based on the work of Gillon (2002) and Gillon and Dodd (1994). It consisted of structured activities to develop the participants' phonological awareness skills in phoneme segmentation, phoneme blending, phoneme manipulation, and tracking sound changes in words. The intervention included activities that allowed the children to identify the link between speech and print. Decoding and encoding of non-words was an integral part of each session. The activities included manipulative materials such as (a) coloured blocks to represent sound changes in words, (b) letter blocks for reading and spelling non-words, and (c) colourful board-game activities for phoneme awareness tasks to help maintain the participants' interest. Senior speech and language therapy students administered the intervention under the supervision of an experienced speech-language therapist.

The study participants with reading disorder experienced 20 hours of the phonological awareness intervention, which was administered two hours per week over a 10-week period. Each participant received one individual session per week and one small group session (with the other three children). The intervention was administered in sound-controlled university clinics after school, and the children continued to receive their regular classroom instruction. No other specialised interventions were received during the period of the study. Post graduate speech-language therapy students who had

received instruction on the intervention implemented it under supervision from an experienced speech-language therapist who had a doctoral degree in speech language therapy and clinical experience in intervention for reading disorders. Treatment fidelity was ensured through the speech language therapy students following a detailed teaching manual and individual session plans. The intervention sessions were videotaped and the supervising speech-language therapist viewed these sessions with the students to provide feedback to ensure intervention content was administered correctly and to comment on improvements for teaching style and interactions.

The children from the NRD group continued to receive their regular class programme and received no other interventions.

### **2.3.1 Phonological awareness assessment probes**

To monitor the success of the pre- and post-phonological awareness intervention, assessment probes were administered in addition to the reading test. These probes were administered by speech-language therapy students. The scores for the reading and phonological awareness probes were independently verified by the author, who was blind (at that time) to the nature of intervention. These probes consisted of tasks that explored the children's ability to track speech sounds using coloured blocks and letter tiles. In each subtest, the children were to arrange the blocks/letter tiles to represent the non-word read out by the examiner and to track the changes occurring in each presentation (e.g., "Show me 'vat.' If that is 'vat,' then show me 'vot'"). For each non-word presented, the children were required to say what had changed and to arrange the blocks /tiles to represent the change. In addition, the children were assessed for their ability to read and spell non-words. The children were scored for the accuracy and the percentage of correct

responses. Probes were given both before and after the phonological awareness intervention. Table 2.2 shows the scores of the RD group on segmentation and tracking speech sounds. The phonological probes were developed to assess change in performance in response to phonological awareness intervention. As the NRD group did not receive any intervention, they were not assessed on the probes. However they were assessed on the same reading and neuropsychological measures as the RD group.

Table 2.2: Effects of intervention on reading accuracy and comprehension

	Reading Accuracy		Reading Comprehension	
	Pre	Post	Pre	Post
RW	10	14	7	8
BA	1	4	7	4
DK	9	17	25	98
JC	3	9	11	25
<i>X</i>	5.75	11.5	12.5	33.75
<i>SD</i>	4.43	6.46	8.54	43.79
<i>t</i> value	3.72*		1.21	
Effect size	0.5		0.32	

Note: Reading accuracy and comprehension percentile rankings from the Neale Analysis of Reading Ability-Revised  
 \*  $p < .05$  *t*-test for two population means (method of paired comparisons).

## 2.4 RESULTS

The RD group was assessed on phonological awareness tests, probes, reading and neuropsychological measures at pre- and post-treatment assessments. The time between these two assessments was 11 weeks. The control group (NRD) was assessed only once on reading and neuropsychological measures.

Student *t*-tests (paired sample *t*-tests) were used to find the significance on the neuropsychological tests between pre- to post-intervention. Effect sizes were calculated according to Cohen's *d* correlation, where 0.2 indicates a small effect, 0.5 indicates a medium effect and 0.8 is indicative of a large effect.

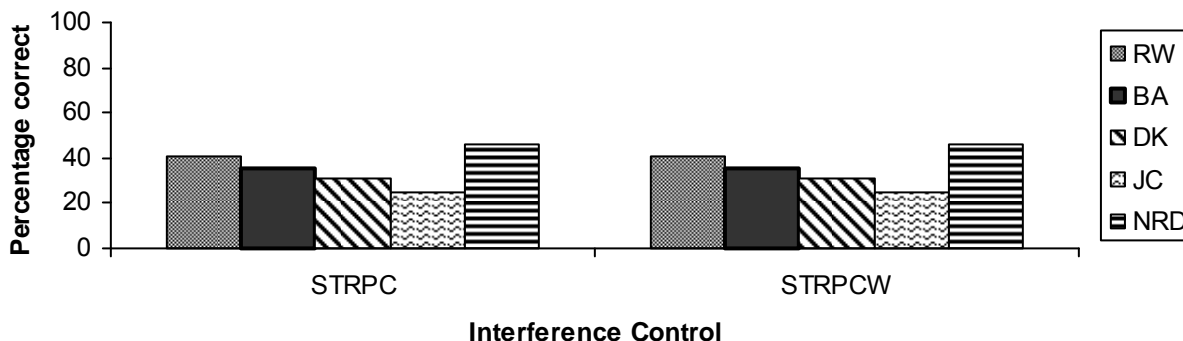
The comparison of the RD group with the NRD group was restricted to pre-intervention assessment only because the NRD group was assessed only once.

Any changes in the RD group at post-intervention could be attributed either to the developmental process or to the intervention. Assessing the NRD group twice with the same time interval of 11 weeks between the two assessments would have helped resolve this issue. However, because the NRD group was assessed only once, we compared the two groups at pre-treatment assessment only.

To assess the effect of intervention, the pre-treatment scores of the RD group was compared with the post-treatment scores. Results are discussed as comparisons of the RD group to NRD group at pre-treatment (see Figures 2.1 and 2.2) to establish presence of neuropsychological deficits and comparison of the RD group scores across the two assessments to assess the effect of intervention.

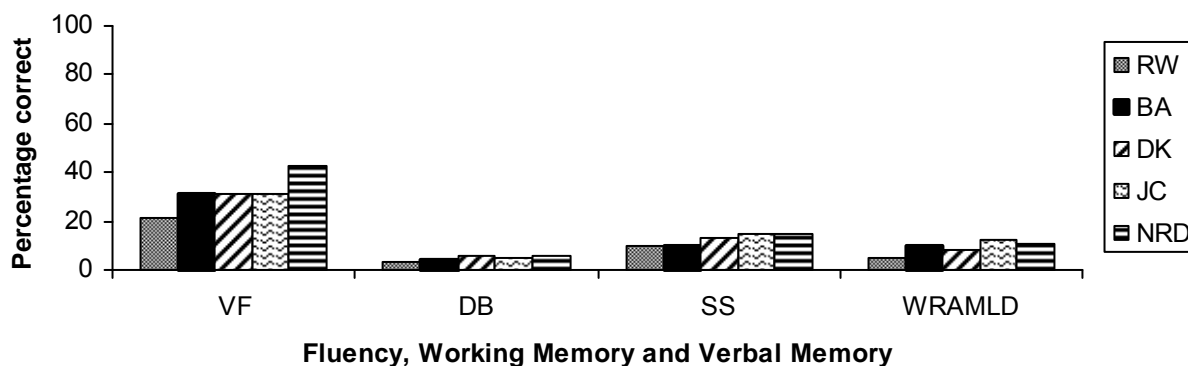
Table 2.2 above and Tables 2.3 and 2.4 show the individual scores of the RD group at pre- and post-intervention assessments on reading (accuracy and comprehension), neuropsychological measures and phonological measures, respectively. Given that the sample size was small, and the variability within the group was found to be large, the individual scores were used in addition to the group scores for comparative purposes. The small sample size means the analysis and interpretation cannot be deemed conclusive. However, the findings did indicate a strong trend.

Figure 2.1: Comparing RD and NRD groups on interference control before intervention



Notes: STRPC = number of words correctly read on colour trials of Stroop Colour-Word Test; STRPCW= number of words correctly read on colour-word interference list of Stroop Colour-Word Test; NRD scores are represented as percentage mean scores.

Figure 2.2: Comparison of executive functions of RD and NRD groups before intervention



Notes: VF = Verbal fluency (COWA); DB = digit span, backward series); SS = spatial span (Corsi block tapping); WRAML = total number of words recalled on delayed recall series of WRAML; NRD scores are represented as percentage mean scores.

### 2.3.1 Reading

Table 2.1 above shows the individual scores on the standardised reading test (NARA, 1988) for both the RD and the NRD groups. Scores (represented as percentile ranks) indicate that the RD group performed significantly lower on reading accuracy and comprehension, compared to the NRD group.

Table 2.3: Effect of intervention on phonological measures

<i>PA assessment</i>	<i>NWR Pre</i>	<i>NWR Post</i>	<i>Blending Pre</i>	<i>Blending Post</i>	<i>Tracking CCVC Pre</i>	<i>Tracking CCVC Post</i>
RW	15	57	52	82	36	100
BA	33	17	49	58	55	55
DK	63	73	67	87	82	91
JC	60	80	74	90	90	100
<i>X</i>	42.75	54.25	60.5	79.25	65.75	86.5
<i>SD</i>	22.90	28.11	11.96	14.55	24.85	21.42
Effect size		0.22		0.58		0.41

*Notes:* NWR = non-word reading; Blending = segmentation-blending; Tracking = tracking of speech sounds using coloured blocks; CCVC = consonant–consonant–vowel–consonant; scores represented as percentage correct.

\*  $p < .05$ ; *t*-test (method of paired sample *t*-tests).

Table 2.2 above shows the post-treatment reading accuracy and comprehension scores for the RD group. The scores indicate that all four children had increased reading accuracy scores after intervention ( $t(3) = 3.72$ ;  $p < 0.05$ ). Reading comprehension increased for three of the four children. This increase was significant for one child (DK). For two of the other three children (RW and JC), the increase indicated a trend towards significance. However, one child (BA) showed a decrease in the post-intervention scores. These individual variations were reflected in the group post-treatment reading comprehension scores ( $t(3) = 1.21$ ), which were not significant. Thus, while reading accuracy increased significantly after intervention, reading comprehension did not show statistically significant improvements.

### 2.3.2 Phonological Awareness

The RD group was assessed on phonological awareness tests and probe measures before and after the intervention. The NRD group was not assessed on these measures. Table 2.3 above shows the performance of the RD group on phonological measures before and after intervention. From the table, it is evident that three of the four children had poorer non-word reading, segmentation-blending and tracking speech sounds before intervention (compared with their post-treatment scores). Individual differences in the pre-post treatment changes were once again noticed within the group. One child (BA) scored higher on non-word reading before intervention and showed no change on tracking speech sounds after intervention. The other three children showed increased non-word reading, segmentation-blending and tracking speech sounds after intervention. Of the three, segmentation and blending skills showed statistically significant change post-intervention (medium effect size = 0.58) followed by tracking speech sounds (small effect size = 0.41).

Table 2.5 shows the comparison of pre-to post-intervention for the RD group. The RD group made significant gains in their post-intervention scores on spatial span (corsi total;  $p = 0.05$ ) and the Stroop Colour-Word Test (colour trial,  $p = 0.001$ ). No significant results emerged for the Trail-making Test ( $p = 0.08$ ) or for other measures such as verbal working memory (digit backward), interference control (Stroop Colour-Word Test, colour-word trial), verbal learning and memory (WRAML total and delayed recall) and visual perception and memory (Complex Figure Test-copy, immediate recall and delayed recall trials).



Table 2.4: Comparing RD and NRD groups on neuropsychological measures

Measures		RD (pre)	NRD	p-value
Verbal fluency (COWA)	<i>M</i>	28.50	42.75	0.07
	<i>SD</i>	5.00	12.42	
Digit backward	<i>M</i>	4.50	6.00	0.168
	<i>SD</i>	1.29	1.41	
Corsi total	<i>M</i>	12.00	14.50	0.196
	<i>SD</i>	2.45	1.92	
Stroop-Colour	<i>M</i>	66.00	8.75	0.227
	<i>SD</i>	18.40	4.57	
Stroop (CW)	<i>M</i>	33.00	46.25	0.075
	<i>SD</i>	6.73	10.34	
Trail-making Test(B)	<i>M</i>	151.75	100.00	0.126
	<i>SD</i>	35.10	18.89	
WRAML-total	<i>M</i>	32.25	37.25	0.373
	<i>SD</i>	9.11	4.99	
WRAML-delay	<i>M</i>	8.75	11.00	0.246
	<i>SD</i>	2.99	1.83	
CFT-copy	<i>M</i>	21.88	29.13	0.355
	<i>SD</i>	13.59	5.01	
CFT-immmediate (imm)	<i>M</i>	14.00	17.750	0.599
	<i>SD</i>	9.703	9.394	
CFT-delay	<i>M</i>	13.62	19.25	0.515
	<i>SD</i>	11.41	11.58	

Notes: RD = children with reading disorder; NRD = no reading disorder; Verbal fluency = Controlled word association; Digit backward = backward series of digit span; Corsi total = Total score on Corsi Block Tapping Test; TMT (B) = Trail-making test, Form B; Stroop Colour = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; WRAML total = total number of words recalled across five trials on WRAML; WRAML-delay = number of words recalled on delayed recall on WRAML; CFT-copy = score obtained on copy trail of CFT; CFT-imm = score obtained on immediate recall trail of CFT CFT-delay = score obtained on delayed recall of CFT  
 $p < .05$ ;  $t$ -test for two population means (method of independent samples)

Table 2.5: Effect of intervention on neuropsychological functions

<i>Measures</i>	<i>RD</i>		<i>p-value</i>	<i>Effect size</i>	
	<i>Pre</i>	<i>Post</i>	<i>Pre-post</i>	<i>Pre-post</i>	
Verbal fluency (COWA)	<i>M</i>	28.50	30.50	0.428	0.168
	<i>SD</i>	5.00	6.61		
Digit backward	<i>M</i>	4.50	4.25	0.391	0.08
	<i>SD</i>	1.29	1.50		
Corsi-total	<i>M</i>	12.00	14.75	0.049*	0.48
	<i>SD</i>	2.45	2.63		
Stroop Colour	<i>M</i>	66.00	67.25	0.802	0.04
	<i>SD</i>	18.40	14.27		
Stroop (CW)	<i>M</i>	33.00	42.50	0.132	0.65
	<i>SD</i>	6.73	3.87		
Trail-baking Test (B)	<i>M</i>	151.75	106.75	0.080	0.54
	<i>SD</i>	35.10	34.89		
WRAM-total	<i>M</i>	32.25	37.75	0.131	0.29
	<i>SD</i>	9.11	8.77		
WRAML-delay	<i>M</i>	8.75	9.25	0.664	0.08
	<i>SD</i>	2.99	2.87		
CFT-copy	<i>M</i>	21.88	20.13	0.537	0.06
	<i>SD</i>	13.59	14.84		
CFT-imm	<i>M</i>	14.00	17.00	0.402	0.123
	<i>SD</i>	9.70	14.01		
CFT-delay	<i>M</i>	13.63	18.50	0.103	0.179
	<i>SD</i>	11.41	15.00		

*Note:* RD = children with reading disorder; NRD = no reading disorder; Verbal fluency = Controlled Word Association; Digit backward = backward series of digit span; Corsi-total = total score on Corsi Block Tapping Test; TMT (B) = Trail-making Test, Form B; Stroop Colour = Stroop Colour-Word Interference Test, colour trial Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; WRAML-total = total number of words recalled across five trials on WRAML; WRAML-delay = number of words recalled on delayed recall on WRAML; CFT copy = score obtained on copy trail of CFT; CFT-imm= score obtained on immediate recall trail of CFT; CFT delay = score obtained on delayed recall of CFT

\*  $p < .05$ ;  $t$ -test (method of paired sample  $t$ -tests)

Post-treatment scores on verbal fluency (Controlled Word Association Test/COWA), set-shifting (Trail-making Test/TMT B), verbal learning (Wide Range Assessment of Memory and Learning, total score/WRAMLT) and visual memory (Complex Figure Test, immediate recall/CFTI) increased for three of the four children. The other child showed no change from pre-intervention to post-intervention.

On other measures, such as interference control (Stroop Colour-Word Test, colour-word trial) and verbal memory (WRAML- delayed recall on Wide Range Assessment of Memory and Learning), two children made gains while one did not show any change and one child had lower scores at post-intervention assessment.. No change was noticed on verbal working memory (digit backward). Thus, although there was an increase in the performance from pre- to post-intervention, this increase was not statistically significant on all neuropsychological tests except spatial span (block tapping) and the Stroop Colour-Word Test (colour trials).

## **2.4 DISCUSSION**

This pilot study explored the effects of phonological awareness intervention on a range of cognitive skills (such as executive functions, attention, verbal learning and memory and visual learning and memory) in a group of children with reading difficulties (RD). It was anticipated that the intervention would improve phonological awareness and reading ability. In addition, we aimed to identify specific cognitive deficits that would respond to the intervention.

The RD group received 20 hours of phonological awareness training. Post-intervention assessment revealed that the children in RD group tended to improve their non-word reading, phoneme segmentation-blending skills and ability to accurately identify changes in speech sounds within syllables. The results from this pilot study also indicated that reading accuracy improved significantly for all four children. This finding accords with other studies reporting that reading skills tend to improve after a structured intervention targeting phonological awareness (Ramus, 2003; Shaywitz et al., 1998; Simos et al., 2002). However, reading comprehension skills did not improve significantly in the RD group. Only one child (DK) showed significant change in comprehension after intervention. The other three children did not show significant changes.

The findings of this study therefore indicate that reading accuracy tended to improve, but reading comprehension difficulties persisted. Despite improvements noticed in phonological awareness abilities, the transfer to comprehension of text did not occur in these children. Earlier studies have pointed to the possible presence of comprehension difficulties and associated oral language difficulties in children with reading disorder (Wise, Sevcik, Morris, Lovett, & Wolf, 2007).

An alternative explanation for the presence of comprehension difficulties associated with reading disorder was proposed. It was hypothesised that the presence of executive function deficits could probably explain the persisting comprehension difficulties present in this group. Executive functions are thought to be an important aspect of cognitive functioning that contributes to reading. In order to comprehend the text while actively decoding the word and retaining word meaning, it is hypothesised that the reader must have intact phonological processing (word decoding), attention, working memory, verbal

memory and oral language abilities. Deficits observed in any or all of these aspects could possibly affect reading accuracy or comprehension. While reading accuracy is thought to be directly associated with phonological processing abilities, comprehension involves several other processes, such as oral language skills, vocabulary and cognitions (intact attention, executive functions and verbal memory). Skills such as executive functions are hypothesised to be required to hold information about the text while reading and make sense of it (Hynd, Semrud-Clikman, Lorys, & Eliopoulos, 1990). The persistent difficulties in reading comprehension seen in the RD group in the current study could possibly be attributed to deficits in executive functioning despite the improved phonological processing observed after intervention. However, as other oral language aspects were not been assessed in this group, the exact contribution of these processes cannot be determined. The presence of executive function deficits, however, remains an important influence on the reading comprehension process.

To better understand the relationship between neuropsychological functions and phonological processing skills in reading disorder, we endeavoured to find out if there were any neuropsychological deficits in the RD group at pre-treatment assessment. The results indicate that the RD group compared to the good readers (the NRD group) had significant difficulties in verbal fluency (as seen on the Controlled Word Association Test/COWA) and inhibitory control. The NRD group scored above the RD group mean on set-shifting abilities, although the difference between the two groups was not statistically significant. All other neuropsychological measures did not reach statistical significance. The small sample size and large individual variances in the group may have influenced the power to detect a true difference.

The difficulties observed in the RD group suggest these children have deficits in executive functioning. Intact executive functioning is hypothesised to be necessary for reading, although it is not directly related to the reading process. It was proposed that persistent executive dysfunctions could probably interfere with the reading process and the reader might not benefit from the phonological awareness abilities that improved after intervention.

The comparison of pre-treatment scores with post-treatment scores helped to identify those neuropsychological functions that improved in response to intervention and those that remained in deficit after the intervention. Visuo-spatial span and interference control showed significant change after intervention. Visuo-spatial span is considered a component of visuo-spatial working memory, which requires visual information to be held online and manipulated (D'Esposito & Postle, 2002). Interference control refers to one's ability to choose relevant stimuli in the presence of distracters. Both spatial span and interference control are essential for overall executive functioning.

Improvements on both these functions suggest that children are able to hold some bits of information in their mind while manipulating other bits of information. For example, the activity involving tracking changes in syllables requires a range of skills. The child is required to represent the syllable “vot” as three different phonemes by using three different-coloured blocks. For success on this activity, it is proposed that the child would be required to hold the sounds online. Then, if the syllable is changed to “vat”, the child must indicate this by pointing to sound that changed, and to demonstrate it by changing the corresponding block. The child needs to hold information online, identify which sound changed and then verify this by comparing the two sounds.

When carrying out this activity, a person would probably be required to draw on working memory (online manipulation) and interference control (interference of previous sounds) to successfully identify the changed sound. Improvements in tracking speech sounds and changes in syllables could possibly be associated with improved visuo-spatial functioning. Similarly, when reading non-words, one has to ignore several competing real-word pronunciations and generate possible alternatives. Thus, successfully executing several of the activities in the phonological awareness intervention could depend on intact executive functions. Repeated exposure to and demands placed on cognitions over time are known to be associated with improvements in these cognitions (Robertson & Murre, 1999). We hypothesised that the nature of the intervention programme and the tasks could possibly be one of the causes attributable to the changes seen in visuo-spatial working memory and interference control in the RD group after intervention.

Associated aspects of cognition, such as verbal fluency, verbal learning and memory and visual memory, did not produce statistically significant changes. However, three of the four children did show improvements on these aspects, indicating a trend towards improvement. The neuropsychological function that did not change after intervention was verbal working memory. This, like visuo-spatial working memory, requires one to hold verbal information online while manipulating it. For reading comprehension, for example, the reader has to hold the meaning of the sentence online while continuing to read in order to understand the text. Because verbal working memory did not show any change after intervention, we hypothesised that the reading comprehension deficits could be associated with the presence of continued working memory deficits in the verbal domain. The child DK made significant gains on measures

of inhibition and set-shifting (both aspects of executive functions) on the post-treatment assessment. Improved executive functions, therefore, could have influenced his post-treatment performance, especially the significant improvement in his reading comprehension. In addition, positive outcome in this child could have been due to the fact that he was older and possibly neuropsychologically more mature than the others in the RD group. We hypothesised that these factors could possibly be attributed to the significant increase in his comprehension scores not observed in the other children. This outcome adds further evidence in support of the notion that improved executive functions are required to improve all aspects of reading (Landi & Perfetti, 2007).

The individual variations in the change pattern noticed within the RD group could have been influenced by age. The two older children (DK and JC) showed greater improvement in their reading comprehension than in their reading accuracy. This trend was not noticed with the younger children (BA and RW).

Typically, the executive functions remain outside the domain of reading, but appear to be essential for the process of reading because they aid in inhibiting interference from irrelevant words/letters during reading. The ability to search for the relevant word sounds or category matches requires intact executive functions. Deficits in executive functioning lead to an increase in errors while reading, making the reading effortful and slow. As the difficulty level increases, the working memory is taxed, and this leads to a breakdown in inhibition control (Brosnan et al., 2002). Lowered inhibition causes irrelevant stimuli to be accepted or responded to. Errors such as guessing words while reading are an indication of poor inhibition control.



The pilot study was a preliminary exploratory study that aimed to identify the cognitive skills that are addressed in phonological awareness intervention for reading difficulties. Although limited by the number of children recruited, the results of this study pointed to some changes in reading and phonological awareness after intervention and revealed the presence of executive functions deficits. Executive functions, such as visuo-spatial working memory and interference control showed improvement after intervention, yet the improvement following intervention remained comparable to that evident within the younger group of good readers. Other neuropsychological deficits, such as verbal working memory, interference control, verbal learning and memory and visual perception and memory, persisted after the intervention. Because the efficacy of this form of intervention has been successful with other groups of children with specific reading disability (Gillon & Dodd, 1995, , 1997), it was hypothesised that the limited response to intervention with the children in the current study could possibly be because of the executive function deficits that persisted after the intervention.

Aspects of oral language functions were not been explored in the current study. It is therefore difficult to estimate the extent of influence the executive functions had on reading comprehension. Questions regarding the influence of improved executive functioning on aspects of reading such as speed and fluency are worth exploring. Previous studies have highlighted the presence of poor responders to phonological awareness intervention (Castles & Coltheart, 2004). Other authors have argued that not all aspects of reading improve in response to phonological intervention (e.g., Torgesen et al., 2001). Future studies that explore aspects of executive function in relation to phonological awareness intervention might help shed light on the effectiveness of

interventions aimed at improving children's word recognition. Intervention targeted at resolving the executive function deficits evident in some poor readers might result in better transfer of skills to the reading process. Studies that aim to include intervention of neuropsychological functions may thus clarify the role of executive functioning in reading.

## **2.5 LIMITATIONS OF THE PILOT STUDY**

Despite identifying the presence of neuropsychological deficits in children with reading disorder and tracing the path of these deficits through intervention focusing on phonological awareness, the current pilot study had the obvious limitation of small sample size. With just four children in each group, who among them showed large individual variations, the ability to generalise findings from the study to a larger population is limited, and conclusive interpretations cannot be made.

A second limitation is the age difference between the groups, with the children in the NRD group being younger than some of the children in the RD group. This placed the older children with RD at an advantage, as they would be more mature neuropsychologically. The profiles of the younger children thus appear to have more deficits in comparison to the older ones, as executive functions are not yet fully developed in these children. Comparing the older children in the RD group with the younger children in the NRD group could produce the conclusion that the RD group did not have deficits. Comparing the RD group with age-matched peers would have yielded a clearer picture about deficit patterns.

A third potential limitation related to the fact that the pre- and post-intervention assessment for the RD group was carried out over a span of 11 to 12 weeks. Practice effects could have influenced the performance of all the children across all tests. However, because all the children in the RD group were retested during this time, we can assume the practice effect was equal for all the children. If the results had been influenced by practice, then improvements would have been seen equally across all parameters. This did not occur for the group. We can therefore assume that practice effects did not influence the scores.

The final limitation is that the children's language skills were not adequately assessed. The children's receptive vocabulary skills were evaluated using the PPVT-IV; however, there was no further assessment of the children's language abilities. Research clearly demonstrates that many children at risk of developing learning disorders do not have isolated phonological awareness problems. Many also have coexisting listening comprehension problems that impact on their ability to read and comprehend text (Catts, Fey, Zhang, & Tomblin, 1999). Although the study children had no documented history of speech and language problems, it is possible they had undetected language difficulties (Nation & Snowling, 1998). Future studies should take this matter into consideration and include more detailed measures of language functioning so that language problems can be ruled out and more definitive statements made regarding the influence of executive functioning on children's reading outcomes.

Despite these limitations, the study identified potential neuropsychological deficits in children with reading disorder and monitored how phonological awareness intervention can influence these. The findings of this pilot study suggest the need to

further investigate neuropsychological deficits in children with reading disorder, and to explore the influence of interventions on these children's other cognitive abilities.

The main study, described in the next chapter, focused on comparing the efficacy of phonological awareness intervention and neuropsychological intervention on specific reading disorder in children from a different cultural and educational milieu compared to the children in the pilot study.

## CHAPTER III

# A COMPARISON OF THE EFFICACY OF PHONOLOGICAL AWARENESS AND NEUROPSYCHOLOGICAL INTERVENTIONS FOR CHILDREN WITH READING DISORDER

### 3.1 INTRODUCTION

Reading difficulty in children affects 5 to 17.5% of the school-age population (Shaywitz & Shaywitz, 2005). Several theories attempt to explain the presence of an inability to read in children and/or adults who otherwise are known to have intact intellectual functioning (Ramus, 2003; Shaywitz & Shaywitz, 2005). The phonological deficit theory posits that reading is a complex activity consisting of two related processes—word-decoding abilities and comprehension. Word-decoding ability is further influenced by the ability to associate sounds to letters. A skilled reader decodes the word successfully and is then able to gather meaning from what is being read. Reading ability and disability occur along a continuum; individuals with reading difficulty are found at one end of this continuum (Shaywitz & Shaywitz, 2005). With age, the difference between a skilled reader and a disabled reader tends to remain constant if intervention does not occur (Shaywitz et al., 1995)

The core deficit in children or adults with developmental reading disorder appears to be in phonological awareness (Lovett & Steinbach, 1997; Ramus, 2003). Many deficits in phonological awareness have been observed in children with reading difficulties, such as phoneme segmentation and phoneme-blending difficulties, as well as difficulties in coding phonological information in working memory (Lovett,

Steinbach, & Frijters, 2000). These difficulties interfere with the individual's ability to accurately decode text and, subsequently, to comprehend written text. Thus, the apparent deficit in reading comprehension is caused by an inability to read the word accurately rather than a difficulty in understanding what is being read (Shaywitz & Shaywitz, 2005). When the same text is read out to the child, he or she is able to comprehend the text and answer questions related to it—a skill referred to as listening comprehension.

Evidence that children with reading disorder have phonological processing deficits comes from several studies that have investigated phonological processing and awareness skills in children and adults with and without reading difficulties (Given, Wasserman, Chari, Beattie, & Eden, 2008; Torgesen, Wagner, Rashotte, Alexander, & Conway, 1997). These studies demonstrate the following: (i) children and adults with developmental reading disorder have phonological awareness deficits; and (ii) fluent readers differ from disabled readers on these and several other parameters. Functional imaging studies and other non-invasive imaging studies have further tested and verified these two postulates.

The current understanding therefore points to the fact that not only do children with reading disorder have deficits on measures of phonological awareness, but that they also engage different areas of the brain while reading compared to the fluent reader. Imaging studies point to the under-activation of the parieto-temporal and temporo-occipital regions of the left hemisphere and over-activation of the left medial frontal lobe by disabled readers in comparison to fluent readers (Given, Wasserman, Chari, Beattie, & Eden, 2008).

Several studies have investigated the benefits of phonological awareness intervention to improve reading performance in children with reading disorder (Given, Wasserman, Chari, Beattie, & Eden, 2008; Shaywitz & Shaywitz, 2005). These studies have found that both children and adults with reading disorder demonstrate improvement in both phonological awareness and reading functions. Improvements were observed in the readers' word-attack skills, word decoding and in their speed of reading. Reading comprehension also improved. The improvement was noticed behaviourally and was indicated as changes in the brain activation patterns after intervention. Intervention programmes have proved to be beneficial for various age groups and well as for use with populations from different educational backgrounds (Gillon, 2004).

Recently, researchers have discussed that although many children demonstrate difficulties with phonological awareness tasks, some do not exhibit phonological processing deficits despite having reading difficulty (Castles & Coltheart, 2004; Given, Wasserman, Chari, Beattie, & Eden, 2008). Also, some children fail to transfer their improved phonological processing ability following intervention to connected reading (Castles & Coltheart, 2004). Their reading continues to be effortful and slow despite their improved phonological processing skills.

Some researchers have highlighted the presence of other cognitive deficits, such as verbal and visuo-spatial working memory, fluency, attention and memory, in children and adults with development reading disorder (Best & Howard, 2005; Price, 2000). Although these cognitive abilities are not directly involved in the process of reading, they play a supportive role during reading (Price, 2000). Cognitive and phonological processing deficits are known to be correlated with the severity of the reading disorder (i.e., the

greater the severity of reading deficits, the greater the cognitive deficits). This recent evidence allows us to conclude that both phonological processing and other cognitive deficits exist in individuals with reading disorder.

However, the deficits are not uniform in all individuals, suggesting the presence of individual differences. How these differences influence the outcome of intervention studies has not been explored. In addition, most remedial studies have focused only on one aspect, which is, addressing either phonological processing or cognitive deficits. Little is yet known about the interrelation between neuropsychological functioning and phonological processing in children with reading disorder. The study reported in this chapter aims to address this need. Specifically, the effect of intervention on both neuropsychological functions and phonological processing abilities is examined. The following questions are addressed in relation to children being educated in a major city in India:

1. What are the neuropsychological and phonological awareness abilities in a group of Indian children with specific reading disorder compared to their peers with average reading ability?
2. What are the effects of phonological awareness intervention on reading, phonological awareness abilities and neuropsychological functioning?
3. What are the effects of neuropsychological intervention on reading, neuropsychological functioning and phonological awareness abilities?

### **3.2 METHODOLOGY**



The study consisted of four phases. Figure 3.1 provides a diagrammatic representation of the procedure, tools and phases of the study.

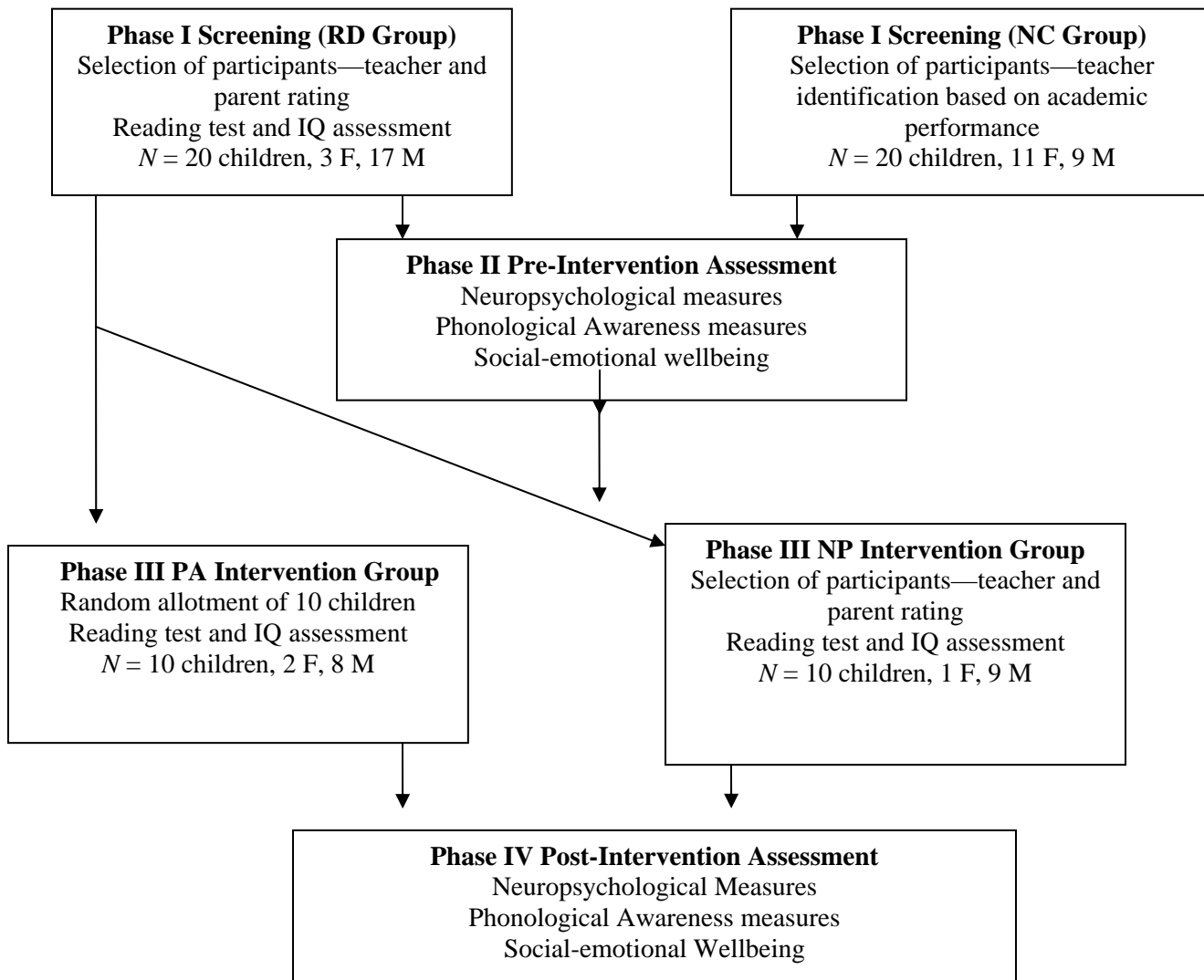
### **3.2.1 Phase I: Screening and Selection of Participants**

#### **3.2.1.1 Specific reading disorder (RD) group**

Children could only be included in the study if they met the following criteria:

1. Aged between 10 and 13 years and studying in Year 5, 6, or 7;
2. Performing at least two years below their expected reading level based on the reading subtest of the NIMHANS SLD Index (Shenoy & Kapur, 1996); and
3. Performing within the average or above intelligence range on the Raven's Progressive Matrix (RPM-Raven, Raven & Court, 2000).

*Figure 3.1: Four phases of the intervention*



Exclusion criteria included presence of psychiatric (behavioural and emotional), neurological and/or language comorbidities. Teachers rated children on the teachers' version of the Child Behaviour Questionnaire (Rutter, 1975). The Developmental Psychopathology Checklist or DPCL (Shenoy & Kapur, 1996) was used to interview parents to assess participants for presence of behavioural and/or emotional disorders. (A description of all tools used in this study is provided in the measurement tools section below.)

Table 3.1 shows the number of children selected from different sources for the purpose of the study. Three schools in Bangalore, India, were approached. Awareness regarding the nature, prevalence and presentation of specific learning difficulties in school going children was low among parents and school authorities. As a consequence, several children with specific learning disorders go unnoticed in schools; in addition they are exposed to ridicule and shame in school. It was felt that if schools were contacted directly, the chance of reaching children with specific reading disorder would be greater. Hence schools were initially approached as first point of contact. Teachers and heads of schools were made aware of the nature of the difficulties present in children with specific learning disorders. The nature and purpose of the study was explained and the consent of the principal obtained to contact teachers of Classes 5 to 7. Teachers were requested to identify children from these classes who had performed poorly scholastically for at least two years. A total of 128 such children were identified by their respective teachers as having academic difficulties. As these children had not been evaluated for presence of specific learning disorders, they were screened for the presence of reading difficulties (using the reading subtests from the NIMHANS SLD index) and intellectual functioning (using the RPM). Forty-four children satisfying inclusion and exclusion criteria were identified.

After the presence of specific reading disorder was identified, parents of these 44 children with specific reading disorder were sent letters explaining that their children were screened for and found to have specific reading disorder. The nature of the difficulty and the intervention targeted in the current study was explained in the information sheet and consent was sought from interested parents to enrol their children

for the programme. Some schools organised a meeting between the researcher and parents of these children to help them come to terms with the difficulties their children faced. They were then explained the need to address their children's difficulties. They were given an option of participating in the study. Relevant information of other available remedial centres was provided for those parents who were not willing to participate in the study. Only six of the 44 parents agreed to participate in the study after this. The teachers of these six children were contacted again and asked to rate these children for presence of behavioural and/or emotional difficulties using the CBQ (Rutter's B Performa; Rutter, 1975). The six children scored below the cut-off (score of 9) on the CBQ, indicating that the behavioural or emotional difficulties reported (if any) were not severe enough to warrant a psychiatric diagnosis of comorbidity. The parents of the six children were asked to complete the semi-structured DPCL. The aim was to further rule out developmental, neurological and/or language difficulties.

*Table 3.1: Selection of participants for intervention: referral sources*

<i>Name of source</i>	<i>Number screened</i>	<i>Number selected</i>	<i>Number participated</i>
Referrals from school	110	28	6
Teacher referral to remedial centres (RC)	16	14	14*
Parental referral remedial centres (RC)	2	2	2
Total	128	44	22

*Note:* \*Two children from this group dropped out after 10 sessions each of intervention.

Sixteen children with reading disorder (using the reading subtest from NIMNAHS SLD index), of average intelligence (based on the percentile score on the RPM) and in the required age range were identified from remedial centres. Children were brought to these remedial centres by their parents after their teachers or friends suggested that the

child be assessed for presence of learning difficulties as the child was consistently underperforming academically. Thus the first step was to establish presence of specific learning disorder in these children. After establishing the presence of specific reading disorder, parents were contacted for consent to participate in the study. Subsequent to obtaining consent, the DPCL with parents and CBQ- Performa B with teachers were administered to rule out presence of comorbid conditions in the children. The total number of children in the study was 22. Two children, one from the neuropsychological intervention group (NP) and one from the phonological awareness intervention group (PA) dropped out after each completing 10 intervention sessions. The total number of participants was thus reduced to 20.

The 20 children selected for inclusion in the study were randomly assigned to one of two treatment conditions. Nine males and one female were randomly assigned to the neuropsychological intervention and eight males and two females were randomly assigned to receive phonological awareness intervention. The characteristics of the group are outlined in Table 3.2.

*Table 3.2: Screening and demographic details of study children with specific reading disorder*

	<i>PA Group</i>		<i>NP Group</i>		<i>p-value</i>	<i>Effect size</i>
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>		
Age	11.63	1.07	11.43	1.28	0.62	0.08
Pre-reading	346.00	144.9	383.00	158.3	0.592	0.12
Rutter B	4.00	2.87	5.5	1.51	0.16	0.31 (S)
Developmental Psychopathology Checklist						
DPCLED	1	0.67	1.4	0.52	0.15	0.31(S)
DPCLCD	0.5	0.85	1.2	0.78	0.07*	0.39(S)
DPCLHK	0.5	0.527	1.10	0.74	0.05*	0.42(S)

*Notes:* N = no effect; S = small effect; M = moderate effect; L = large effect; VL= very large effect; \* $p < .05$ ; \*\* $p < .01$

PA group = phonological awareness intervention; NP group = neuropsychological intervention; DPCLED = Developmental Psychopathology Emotional Disorder subscale; DPCLCD = Developmental Psychopathology Conduct Disorder subscale; DPCLHK = Developmental Psychopathology Hyperkinesia Disorder subscale

All children belonged to middle socioeconomic status (based on reporting of family annual income). Their respective ages, reading scores, Developmental Psychopathology Checklist (DPCL) data and Rutter's Proforma B data are reported in Table 3.2. The scores on the DPCL are based on a semi-structured parental interview; the Rutter's Proforma B is a teacher rating scale.

The figures in Table 3.2 indicate that the two treatment groups were comparable on age, education and reading scores. The NP group differed significantly from the PA group on the conduct disorder (DPCLCD) and hyperkinesia subscales (DPCLHK) of the DPCL. Although the NP group scored higher on these two subscales compared to the PA

group, the scores were not above the cut-off, suggesting that the behaviour problems and hyperactivity reported by the parents in the NP group were not severe enough to warrant a clinical diagnosis.

### 3.2.1.2 Control (NC) group

In order to identify how children with specific reading disorder differed from typically developing children, a group of average readers were included in the NC group. Children from Classes 5 to 7 were selected for inclusion into the study by their teachers. The criterion for selection was their performance in school. Children, who in the last two academic years, were in Grades B or B+ (i.e., achieving 60–75% marks in all subjects) were sent information and consent forms for parents to complete. Twenty children who had signed parent consent forms were then randomly selected for the study. They were assessed on the reading subtest of the NIMHANS SLD battery to ensure average reading ability. All 20 children had age-appropriate reading scores. Table 3.3 compares the two groups (i.e., RD and NC) on socio-demographic variables. The reading scores are reported in Table 3.4.

*Table 3.3: Demographic details of RD and NC groups*

<i>Basic characteristics</i>	<i>Control group</i>		<i>Reading disorder group</i>	
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>
Age in years	11.56	0.74	11.57	1.16
Years of schooling	8.10		8.15	
Gender				
M	9		17	
F	11		3	

It is evident from Table 3.3 that the two groups were comparable in terms of their age and years of schooling. The two groups differed with regard to their reading scores (Table 3.4). The scores indicate the mean number of words accurately read by the respective groups. The  $p$  value and large effect size suggest that the two groups were significantly different in their reading ability. The standard deviation of the experimental group indicates that there was individual variation within the treatment group on this score.

*Table 3.4: Reading scores of the normal control and reading disorder groups*

<i>Tests</i>	<i>NC group</i>		<i>RD group</i>		<i>p value</i>	<i>Effect size</i>
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>		
Reading	490.90	68.6	364.50	149.0	0.001**	1.07(L)

*Note: \* $p < .05$ ; \*\* $p < .01$*

### **3.2.2 Phase II: Pre-treatment Assessment**

Before the onset of the intervention, the children in the RD group were assessed by the author on neuropsychological tests and phonological awareness measures. The assessment was carried out in individual sessions in a quiet setting and was conducted across two to three sessions. Each session lasted about two hours. Children were given breaks between the tests to ensure adequate attention and motivation levels. All the assessment sessions were videotaped and later verified by another individual for consistencies in scoring and administration. The scoring and administration procedures accorded with the method specified in the respective manuals and books.



The NC group was measured on the same neuropsychological tests as the RD group. Phonological awareness was measured using the Queensland University Index of Literacy (QUIL; Dodds et al., 1996). Section 3.4 details the assessment measures used.

### **3.2.3 Phase III: Intervention Phase**

After the pre-intervention assessments, the two intervention groups, namely the phonological awareness intervention (referred to as the PA group) and the neuropsychological intervention (or the NP group) received 20 sessions of intervention, spread over three to four months. All intervention sessions were administered individually by the author to each child during two 40-minute sessions per week. The author provided intervention for each of the 20 participants to control for differences in instructor style or personality during the interventions. The sessions were administered in a quiet room in the child's school for all the children.

Five children were provided with intervention during school hours at times allotted by their teachers. For all other children, the sessions were conducted in a quiet, distraction-free room after school hours. Sessions used simple paper and pencil tasks and game activities. Both intervention programmes were similar in the type of teaching activities used, but the content of the activities differed. For example, the phonological awareness intervention focused on enhancing phonological abilities while the neuropsychological intervention aimed at enhancing cognitions such as attention, scanning and memory. Descriptions of the two treatment programmes and of the rationale behind each of the treatments follow the description of screening and assessment tools.

### **3.2.4 Phase IV: Post-intervention Assessment**

After completion of the 20 intervention sessions for the 20 children with specific reading disorder, the children were assessed on the same neuropsychological, phonological and social-emotional measures that were used for the pre-intervention assessment.

## **3.3 ASSESSMENT MEASURES: TOOLS USED**

This section provides a description of the assessments used during the screening and the pre-intervention and post-intervention assessments. The assessments are described under the following headings:

1. Participant selection
2. Screening
3. Neuropsychological
4. Phonological
5. Social-emotional.

### **3.3.1 Participant Selection**

#### **3.3.1.1 The Child Behaviour Questionnaire/CBQ (Rutter, 1975)**

The CBQ is a rating scale that measures learning, emotional and behavioural difficulties in children and consists of two proformas—A and B. The scale is available as three versions: parent rating, teacher rating, and self-rating. The teacher-rating version was used in the current study. Proforma B was used to help exclude children with behavioural and emotional problems. Performa B consists of 26 items that are rated as present sometimes, often or never. Each statement is given a score of 1, 2 or 0. Scores obtained on all items are totalled to obtain a total score. A total score of nine and above indicates

clinically diagnosable emotional/behavioural difficulty. The scale has good reliability and validity. It correlates significantly (0.69) with the Child Behaviour Checklist (CBCL).

### **3.3.1.2 The Developmental Psychopathology Checklist/DPCL (Kapur, Barnabas, Reddy, Rozario, & Hirisave, 2002)**

The Developmental Psychopathology Checklist (DPCL) helps identify child psychopathology from a developmental perspective. It includes autism, developmental disorders, late-onset childhood psychoses, hysteria and learning disorder in addition to disorders of emotion, conduct and hyperkinesis. For the purpose of this study, the items for emotion, conduct and hyperkinesis were used and administered in the form of an interview.

The checklist items act as guidelines and form the basis of the questions parents/guardians are asked to elicit information about their child's behaviour. If the target behaviour is present, it is scored as 1; if absent, it is scored 0. For each subunit, the total number of items scored is noted and reported. Each subunit has cut-off scores. A score above the cut-off on a particular scale indicates a condition severe enough to warrant a clinical diagnosis. The tool is validated against the Child Behaviour Checklist and has a reliability of 0.965 (Kapur, 2002).

## **3.3.2 Screening**

### **3.3.2.1 Raven's Progressive Matrices (RPM)**

The Coloured Progressive Matrix (CPM) (Raven, Raven, & Court, 1998) or the Standard Progressive Matrix (SPM) (Raven, Raven, & Court, 2000) were both used, but the choice of which to use with a particular child depended on his or her age. CPM was used for children 11 years and below while SPM was used for children 12 years and above.

The RPM is a measure of non-verbal intelligence. Both tests consist of problems divided into sets of 12 problems each. The problems become progressively more difficult, with the last problem considered the most difficult. Each problem consists of a large picture with a portion of it missing. Using the choices given below the large figure to assist them, the children had to identify the choice that will help them complete the figure. Answers are scored right or wrong based on a key provided. Each right answer obtains a score of 1; a wrong answer gets a score of 0. The number of right answers forms the total score. This score then is used to determine a percentile score for each child, and it is this that indicates his or her range of intellectual functioning.

The CPM has been found to correlate significantly with the full scale IQ (0.50) and performance IQ (0.70) on Wechsler's Intelligence Scale for Children (WISC). Factor analysis studies suggest that SPM is a measure of simultaneous processing and that it measures other factors in addition to general intelligence, such as spatial ability (Raven et al., 2000).

### **3.3.2.2 NIMHANS SLD Index Reading and Spelling Subtests (Kapur, Hirsave and O'Omen, 2000)**

This individually administered multiple-subject comprehensive test covers reading, mathematics, language skills and writing. It is designed for children and young people between the ages of 5 and 14 years. Only reading and spelling subtests from the complete index were assessed for the present study. The subtests used for the study included reading passages (I-VII), spelling (passage-related and individual lists), reading comprehension, and written expression.

### **3.3.3 Neuropsychological**

The neuropsychological assessment was conducted using a battery of tests from the NIMHANS Neuropsychological Battery for Children. Some other independent tests outside of the battery were also chosen.

#### **3.3.3.1 Number Cancellation Test (Kapur, 1974)**

This is a measure of sustained attention and visual scanning. Each child is presented with a sheet of paper that has several randomly generated numbers on it. The numbers range from one to nine. The child is asked to cancel out two target numbers specified before commencing the task. The time taken, the number of omissions and the number of commission errors are noted. Normative data collected in the Indian population indicates that the performance on this test is influenced by age. Children in class five were able to cancel 56 numbers in one minute and had 13 omissions on average.

#### **3.3.3.2 Verbal Fluency: Controlled Word Association Test/COWA (Lezak, 1995)**

The Phonemic Fluency Test is a measure of verbal fluency. It evaluates spontaneous production of words beginning with a letter within a limited time. The children are each asked to generate as many words as possible that begin with a given letter. They are instructed not to give the names of people and places and not to repeat words. A time limit of one minute per letter is given. Each child is given three letters, and the number of words generated for each letter is noted down. An fMRI study of brain activity during a verbal fluency task showed activation in left prefrontal and right cerebellar regions (Schlosser et al., 1998).

### **3.3.3.3 Colour Trails Test (D'Elia, Satz, Uchiyama, & White, 1996)**

Colour Trails is a measure of focused attention and cognitive flexibility. The test has two parts—Trail “A” and Trail “B”. In Trail A, the numbers 1 to 25 are presented in coloured circles—pink for odd numbers and yellow for even numbers. The children are individually asked to connect the numbers in a serial order. Their attention is not drawn to the coloured circles. The time taken and the number of errors made are noted. Trail B shows all numbers from 1 to 25 twice (the first time in pink and the second time in yellow). Each child is instructed to connect the numbers serially from 1 to 25 while alternating between the pink and yellow circles. Time taken and number of errors are noted. The test–retest reliability for Colour Trails is reported as 0.64 for Trail A and 0.78 for Trail B (D'Elia et al., 1996). Correlation between Trail Making Test is reported to be 0.41 (Colour Trail A) and 0.50 for Colour Trail B. The test is a measure of visual scanning with a motor component. Motor speed makes an important contribution to the task (Lezak, 1995).

### **3.3.3.4 Corsi Block Tapping Test (Corsi, 1970)**

This test is used to assess visual short-term memory and implicit visual-spatial learning. It is used for people six years of age and over. The Block Tapping Test used to register the immediate block span assesses the capacity of the visual-spatial subsystem within the short-term memory. The test consists of nine blocks placed in front of the examinee. The examiner taps the blocks in a sequence that grows with each segment and the examinee is expected to repeat this. The test on block tapping is reported to be one block lower than the digit span test (Spren & Strauss, 1998). Moderate test-retest reliability was reported in neurological populations (Lezak, 1995).

### **3.3.3.5 The Digit Span Test**

Digit Span is a WISC-III subtest consisting of two series—forward and backward. Digit forward consists of a series of numbers two to nine digits long; digit backward consists of digits two to eight digits long. The child is asked to listen attentively while a string of numbers is read at an even pace. After the digits are read out, the child is asked to repeat them in the same order (in digit forward) and in reverse order (in digit backward). The score is a total of digits correctly recalled in forward and backward trials. Digit span is a measure of attention (forward series) and working memory (digit backward). It is a reliable subtest with reliability co-efficients ranging from 0.79 to 0.91.

### **3.3.3.6 The Stroop Colour-Word Test (Golden, 1975)**

One measure of executive function is the Stroop Interference Test, originally developed in 1935 by Stroop to measure selective attention and cognitive flexibility. It is most often described as measuring the individual's ability to shift cognitive set (Spreeen & Strauss, 1998); it is also believed to provide a measure of cognitive inhibition (Homack & Riccio, 2003) or the ability to inhibit an over-learned (i.e., dominant) response in favour of an unusual one (Spreeen & Strauss, 1998).

The task has three components. First, the individual is asked to name a series of colour words (word task). Second, the individual is asked to name the colour of a bar (colour task) of Xs (e.g., XXX in red, blue or green ink). The final task is the colour-word task on which the individual is shown the names of colours printed in conflicting ink colours (e.g., the word blue in red ink) and then is asked to name the colour of the ink rather than the word. The test had moderate test-retest reliability ( $r = 0.54$ ) and Spreeen and Strauss (1998) report that for the colour-word interference trial only the second

administration is associated with practice effects. However repeated administrations beyond the second are not known to be associated with practice effects.

### **3.3.3.7 Rey's Auditory Verbal Learning Test/RAVLT (Who/UCLA version) Maj et al., 1983)**

This test is a measure of verbal learning and memory. It measures immediate memory, acquisition of new learning, retention, primacy and recency effect, and is susceptible to proactive and retroactive interference. The test is sensitive to deficits of specific components of verbal learning and memory (Elger et al., 1997). It consists of two lists of 15 words each. List 1 is presented five times; after each trial, the child is asked to recall as many words as he or she can remember. The verbatim recall of the child is noted. After the fifth trial, List B is presented, and the child is asked to recall the new list. He or she is then asked to again recall words from List A, as a measure of the role interference (retroactive/proactive) plays in verbal learning and memory. After a 30-minute delay, the child is once again asked to recall words from List A. With each trial, the total number of words correctly recalled forms the score. Age, education, gender, verbal ability and general mental ability affect performance on the test (Lezak, 1995). Factor analysis studies indicate three factors measures by this test namely acquisition, storage and retention. The test has moderate test–retest reliability over a one-year interval (for total number of words recalled = 0.77), and it correlates moderately well with the California Verbal Learning Test (CVLT), a test of similar design.

### **3.3.3.7 Rey-Ostrrieth Complex Figure Test (CFT)**

This test assesses visuo-spatial constructional ability and visual memory. The measures of performance include a copy score that reflects the accuracy of the original copy and is



a measure of visuo-constructional ability. They also include immediate or 5-minute- and 30-minute-delayed-recall scores; these provide a measure of visual memory based on the number of facts recalled during each trial. Several scoring systems are available for the test. In the current study the Taylor method (Taylor, 1959) has been used. The test is a test of visuo-spatial organization and factor analysis studies indicate that the copy trial of the test has a high loading of planning and organization skills (Lezak, 1995). Small effects were found for education while age differences did not influence the score on the copy trial (Spren & Strauss, 1998). Interrater reliability for the test is reported to be high ( $r = 0.95$ ) (Lezak, 1995)

#### **3.3.3.8 Block Design Test or MISC (Malin, 1969)**

The Block Design Test is a measure of visuo-constructive ability, analytical and synthesis ability and Gestalt perception. This test is part of an Indian adaptation of Wechsler's Intelligence Scale for Children (Malin, 1969). The test consists of 10 designs presented individually on each card. The children are individually given a set of blocks, each of which has two sides that are coloured red, two sides that are coloured white and two sides that are half red and half white. The children are instructed to arrange the blocks to look like the design presented before them. Scores are given based on the time taken to complete the design within the specified limit. If a child fails to complete the task within the specified time limit, he or she is set down as having failed the task. The test is stopped after two consecutive failures. Cards A, B, C and numbers 1 to 4, require four blocks; numbers 5 to 7 require nine blocks. The time limit varies, with 45 seconds for cards A, B and C, 75 seconds for Cards 1 to 4 and 150 seconds for cards 5 to 7. Scoring and extra scores based on time taken are carried out according to the manual. The split half

reliability co-efficients (described in the manual) range from 0.83-0.89. Test retest reliability for neuropsychiatric patients was found to be moderate ( $r = 0.63$ ) after (Lezak, 1995). Factor analytic studies reveal that the test loads high on perceptual organization factor, visuo-construction and general mental abilities (Benton, 1984).

### **3.3.4 Phonological**

Phonological awareness was assessed using the Queensland University Inventory of Literacy (QUIL), The Stahl and Murray Non-word Reading Test, a spelling probe and a tracking speech-sound probe.

#### **3.3.4.1 The Queensland University inventory of Literacy/QUIL (Dodd et al., 1996)**

This test consists of a series of tasks designed to measure children's phonological abilities. It consists of several subtests measuring syllable identification, syllable segmentation, non-word reading and non-word spelling, rhyme (spoken and visual rhyme detection) and spoonerism, to name a few. Each subtest has discontinuation rules, and the number of correct responses for each item forms the subtest score. The test has been standardized on Australian children from Grades 1 to 6 (6- to 12-year-old children).

#### **3.3.4.2 Stahl and Murray Non-word Reading Test**

This test consists of three sets of words of increasing difficulty level. The children are each asked to read the word as best they can. The children's responses are recorded verbatim. A word correctly read gets a score of 1. Incorrect reading of the word is noted as an error. If the child makes four consecutive errors on Set I, the list is discontinued and the next list is presented. For Sets II and III, the list is discontinued after three

consecutive errors on each list. The number of words read correctly is noted. In addition, the number of phonemes read correctly for each word is noted and totalled across all the words read by the child.

### **3.3.4.3 Spelling probe**

A list of 18 words is read out to the children, after which each child writes down the spelling for the word. The total number of words and phonemes correctly spelt is noted.

### **3.3.4.4 Tracking speech-sound probe**

This task is based on the training programme used in the study (Gillon & Dodds, 1994, 1995). It requires children to identify sound changes in words through the use of coloured blocks and then through the use of letter blocks. Three lists of non-words are presented to each child, and he or she is asked to represent the sounds heard using the coloured blocks or letter tiles. The lists differ in the difficulty level based on the consonant–vowel patterns within the non-words. List 1 consists of words with the consonant–vowel–consonant pattern (CVC). List 2 consists of non-words in the consonant–consonant–vowel pattern (CCV), and the third list is made up of consonant–consonant–vowel–consonant (CCVC) pattern. The number of correctly represented sounds forms the score for each list. Appendix 3 lists patterns of CVC, CCV and CCVC patterns.

## **3.3.5 Social-Emotional**

### **3.3.5.1 Beck’s Youth Inventories/BYI (Beck, Beck, & Jolly, 2001)**

Beck’s Youth Inventories (BYI) was used to assess the children’s social-emotional status. The BYI is a set of norm-referenced diagnostic scales for children and youth ages 7 to 15.

It is designed to assess five areas of social-emotional status: depression, anger, anxiety, disruptive behaviour and self-concept. The five inventories each contain 20 statements about thoughts, feelings and behaviours associated with emotional and social impairment in youth. Children describe how frequently the statement has been true for them during the past two weeks, including today.

Each inventory in the BYI takes approximately 5 to 10 minutes to administer. The full inventory (i.e., includes all five scales) takes approximately 30 to 60 minutes to administer. Each inventory consists of 20 self-rated items on a four-point scale of 0 to 3. Each scale yields a single raw score that can be converted into a *T*-score. The *T*-score is used to interpret the degree of distress experienced by the individual. High *T*-scores indicate high levels of distress, and low *T*-scores indicate lower levels or no distress. The *T*-scores can be compared to the normative sample scores to determine the individual's relative deviation from the mean of the normative group.

The norms for the BYI-II were developed using two general population samples and one clinical sample. Two kinds of reliability are described in the manual. Internal consistency range, across all five scales, from 0.86 to 0.91 for ages 7 to 10; 0.86 to 0.92 for ages 11 to 14; and .91 to .96 for ages 15 to 18. Test-retest reliabilities are in the ranges of 0.74 to 0.90 for ages 7 to 10; 0.84 to 0.93 for ages 11 to 14, and .83 to .93 for ages 15 to 18. Convergent validity ranging from 0.69 to 0.77 was reported for each one of the clinical scales.

## **3.4 INTERVENTIONS**

### **3.4.1 Neuropsychological Intervention**

#### **3.4.1.1 Rationale**

The current study provided neuropsychological intervention for an array of cognitive deficits known to be associated with reading disorder. The intervention draws from two principles of rehabilitation—functional reorganisation within the target circuit and neuronal plasticity. Tasks were developed drawing from knowledge of the deficits present and the anatomical regions involved in their functioning.

In the training programme, tasks were arranged in a hierarchical fashion (starting from low levels of complexity) and given repeatedly over a period of time based on the Hebbian principle of learning, which states that “cells that fire together wire together” (Robertson & Murre, 1999). Tasks given repeatedly in a hierarchy ranging from simple to difficult are hypothesised to stimulate the circuits thought to underlie specific dysfunctions. Stimulating circuits repeatedly is thought to be associated with plasticity within the targeted circuits. Plasticity, in turn, probably would result in better cognitive functioning. Repeated presentation of tasks over time targeting those cognitive abilities hypothesised to be associated with reading is proposed to enhanced cognitive functioning. In turn, the enhanced cognitive abilities that are assumed to underlie or support reading would possibly result in better reading skills. The cognitive abilities though to be associated with reading are reported to be attention, executive functions (such as verbal fluency) working memory, and memory (both verbal and visual).

In the remedial programme, a baseline for each child was established on each of the tasks described below. The baseline for that task was the lowest level at which the child

could achieve 50-60 % accuracy. All tasks were first presented at baseline level for each child. Moving on to the next difficulty level depended on how well they perform on the task within a session. Targets for each task were set at the beginning of the session. The target could be the number of words generated, the number of correct responses or the time taken to complete the task. Feedback regarding each child's performance after completion of each task was provided immediately. The target for the next session was based on the performance of the child in the previous session. If he or she reached the target set over two consecutive sessions, the next level of difficulty was introduced. The difficulty level was increased by making the target more difficult or by changing the items within the task to make it more difficult for the child.

The neurocognitive tasks that were used in the study are described in the next section.

#### **3.4.1.2 Tasks for attention and scanning**

Attention is hypothesised to be a secondary process in reading but without it, the process of reading cannot be adequately carried out. Commonly seen attentional deficits are selective attention and divided attention deficits. Scanning is another deficit that is closely related to attention. Scanning requires the individual to engage and disengage attention in order to perform adequately on tasks requiring this process. Dass (2000) and Price (2000) both point to attentional deficits in disabled readers. The anatomical regions involved in attention such as the frontal parietal and thalamic regions (Posner & Peterson 1990) show dysfunctions in disabled readers (Galaburda, Sherman, Rosen, Aboitiz, & Geschwind, 1985; Paulesu et al., 1996; Shaywitz et al., 2002). The attention tasks used in the study included:

- *Letter cancellation:* Each child was required to score out specified letter(s) from a printed page of a magazine/newspaper. One or two letters were set as the target at the beginning of the task. The target chosen included frequently letters from the English alphabet (e.g., vowels and consonants such as A, E, I R, T, F, M, S). The number of errors made in the form of omissions and/or commissions were noted for each session. The task was initially made easy by having single letters for younger children and one- vowel/one-consonant combinations for the older children. Thereafter, the difficulty level was increased until the child was able to cancel two vowels (e.g., A and E) without omitting target letters and maintaining constant time. Each time the child reached a level of fewer than five errors within the given time of 10 minutes, the next level of difficulty was introduced on this task. This task was given for 10 minutes and for all sessions until the sixth, when it was given alternatively with the shading task.
- *Grain sorting:* A mixture of three kinds of grains was set before each child. The child was instructed to separate the grains into three groups, each containing only one kind of grain. The task was first given as an attention task, which meant the child did not have to do any other task/activity while sorting. Later, the task was used as a divided attention task in that the child was required to do other tasks while sorting grains. The child was initially given two to three tablespoons of the grain mixture. This amount was later increased to four spoonfuls, and the child was given other tasks, such as fluency, temporal ordering and frequency encoding, along with grain sorting. The time given to complete the task was about 10 minutes.

- *Shading*: A complex geometric figure with several compartments was drawn on a sheet of paper and placed before the child. He or she was asked to use a pencil to shade each compartment within the figure. While shading, the child was asked to keep in mind several rules: (i) keep the shading light and even (i.e., do not use pressure); (ii) shade only one compartment at a time; (iii) keep the direction of shading within each compartment constant; (iv) remain within the boundaries of the compartment drawn. These rules ensured that the child paid attention to the task on hand. The task was hypothesised to enhance sustained attention.

#### **3.4.1.3 Tasks for executive function and working memory**

Neuropsychologists propose that individuals with executive function impairments possibly display problems in initiating or ceasing of activities, making mental/behavioural shifts relative to attention and awareness of self and others. Component processes hypothesised to support executive control include activation/drive systems, inhibitory control, working memory, interference control, prospective memory and self-monitoring/regulation (Mateer, 1999)

Deficits in working memory and an inability to shift attention have been reported in individuals with reading disorder (Price, 2000; Shaywitz et al., 1998; Temple, 2002). In terms of anatomy, the prefrontal lobe and the temporal lobes have been found to be involved in executive functions. Research points towards deficits in this region in reading-disabled individuals. Adequate working memory is hypothesised to be involved in various higher order functions in reading (Price, 2000; Swanson, 1999). Hence, executive functions were targeted in the study using these tasks:



- *Number manipulation:* A series of single-digit numbers were read, one after the other, to the child. The child was required to call out the sum of two consecutive numbers each time. Fifty such numbers were presented continuously. The time taken and errors made while adding or remembering the previous number was noted. The number of times the child forgot the previous number was noted down as a restart. The child was given feedback regarding the time taken and number of errors made. This feedback was used to set the target for the next session. Initially, the target for the child would be to ensure zero restarts and few errors. Once this target was reached, another target was set, that of taking two to three seconds per calculation. And when this target had been met, the difficulty level was increased through inclusion of higher-value numbers. The target also changed in line with the range of numbers used. Initially, numbers from one to four only were used. As the child's accuracy increased, larger numbers (five to nine) were added. This activity was introduced after the third intervention session; in the latter part of the intervention, it was presented alternatively with a continuous phoneme recognition task.
- *Phonemic fluency:* The aim of this activity was for the child to generate as many words as possible starting from a target letter. The time limit set for it was two minutes. Three such trials were given to the child. For each letter, the feedback of number of words generated was given both in terms of total number and number per 30 seconds to allow the child to understand the concept of fatigue while searching for words. A target of 20 words was set for each letter. Initially, frequently occurring letters such as M, B, T were used. Once the child reached the

target, less frequently occurring letters such as K, N and J were used. Letters F, A and S were not used in the training sessions because these formed part of the assessment battery. During the activity, which was given during each intervention session, the child was given clues to help him or her generate the words. In later sessions, however, the child received no such help, and the expectation set for him or her was to reach the target of 20 words per letter each in a span of two minutes.

- *Continuous phoneme tracking:* A number of phonemes were presented in rapid succession. The child was required to react in a predetermined way to a target phoneme, which was identified before the trial began. The number of errors he or she made was recorded. Initially, only sounds were used, with the target phoneme presented in the beginning, middle and/or end. Over time, more words with sounds close to the target phoneme were included as distracters. Fifty such words were presented each time, and the child had to tap when he or she heard the target sound. About 20 words had the target phoneme.

#### **3.4.1.4 Tasks for memory and visuo-spatial processes**

Severe delays in time-duration awareness, sequential-naming problems for concepts pertaining to time (such as the days of the week), errors in time relocation of memories and vagueness of temporal distance or remoteness appreciation are among the deficits noticed in children with reading disorder (Habib, 2003). These impairments are hypothesised to occur with temporal processing difficulties. Memory is another function thought to be anatomically associated with the temporal lobes (Buchner, 1999; Joseph, 1986; Wagner, 1999), while the visuo-spatial functions are hypothesised to be associated with the parietal lobes (Joseph, 1986; Jonides, 1996). These regions have been repeatedly

found to show dysfunctions among disabled readers (Brunswick, McCrory, Price, Frith, & Frith, 1999; Hynd, Semrud-Clikman, Lorys, & Eliopoulos, 1990; Rumsey et al., 1992; Simos, Brier, & Fletcher, 2000). The following tasks are hypothesised to enhance memory, and accordingly were used in the rehabilitation.

- *Temporal encoding:* A list of words divided into three groups was read out, one group at a time, to the child, who was expected to learn and remember the words in one group before moving onto the next. Once the child had learned the words in all three groups, he or she was asked to recall the entire list. Three such lists were given. The number of words correctly recalled in each trial was noted and given as feedback to the child. After being taught strategies such as making a sentence with the words and using visualisation to hold onto the information, the child was then encouraged to use it on his or her own in subsequent lists/sessions. At first, the lists were six words long, with two words in each group (2+2+2). With practice, the child got to point of being presented with nine words (3+3+3), 12 words (4+4+4) and 15 words (5+5+5) per list.
- *Frequency encoding:* The child was presented with a list of words in which some words were repeated more than once while others occurred only once. The child had to listen to the list and then recall (i) the words called out, and (ii) the number of repetitions for each word. Initially, a list of 10 words was given, with one word repeated four times, one three times, one twice, and one only once. Three such lists were given. As the child's recall became more accurate, the number of repetitions was reduced and the number of words increased per list.

Although the tasks were broadly classified into the three cognitive domains, they were hypothesised to overlap and possibly target similar cognitive abilities. In addition to including attention, executive function and memory, some tasks possibly include a motor component hypothesised to be a cerebellar function (Nicolson, Fawcett, & Dean, 2001).

### **3.4.2 Phonological Awareness Therapy**

#### **3.4.2.1 Rationale**

Various researchers have found that phonological awareness deficits among disabled readers (Brunswick, McCrory, Price, Frith, & Frith, 1999; Paulesu et al., 1996; Shaywitz et al., 2002; Temple, 2002). Although evidence points to the benefits of phonological awareness intervention on reading, it has not been unequivocal. In the current study, we attempted to provide two kinds of interventions for reading. We hypothesised that, in addition to changes in reading ability, the cognitive functions and phonological skills would show differential improvement depending on the intervention provided. The study therefore attempted to compare the well-established phonological awareness intervention with a neuropsychological intervention and to assess the efficacy of each programme on reading ability.

#### **3.4.2.2 Description of phonological awareness therapy**

The phonological awareness (PA) intervention employed in the current study was based on the research of Gillon and Dodd (1994, 1995, 1997) and detailed in Gillon (2000). This intervention was developed for use with children with specific reading disorders and children with spoken language difficulties, and it has been successfully implemented with

children in New Zealand, Australia and the United Kingdom (Denne, Langdown, Pring, & Roy, 2005). The programme activities target phoneme segmentation, phoneme blending, phoneme manipulation and tracking speech sounds changes at the phoneme and syllable levels. Activities, games, flash cards, coloured blocks and letter tiles were used as aids during the intervention programme.

The initial intervention session aimed to establish the basal level of each child across the activities. Each of the participating children was trained on those activities with which he or she had difficulties. The level at which the training started depended on the child's basal level of functioning. For example, younger children required more training on the phoneme isolation and identification aspects. Thus, the first three sessions were devoted to training identification and isolation. These skills were introduced to the older children during the first session. Subsequent sessions focused on tracking speech sounds, because these presented the children with considerable difficulties.

The tasks used and the skills training were similar for all the children, but the level of difficulty and time that each spent on the activities differed. The rate at which the children moved from one difficulty level to the next also depended on their own performance. At each difficulty level, the child was assessed for accuracy. If the accuracy was at or above 85%, on a particular task, the next level of difficulty was introduced.

The 20 sessions comprising the intervention tackled similar skills through use of different activities, and the two RD groups engaged in the sessions simultaneously. For the entire period of intervention, the children received regular class inputs along with the intervention provided for the study. The children did not receive any additional

remediation (other than classroom instructions) for their reading difficulties during the period of the study.

#### *3.4.2.2.1 Sessions 1 to 3*

Letter tiles were introduced to all children during the first session so as to familiarize them with all the letter-sounds and phonemes present in the English language. The subsequent sessions focused on isolation, identification, and segmentation of picture names at the phoneme level. For example:

- Tell me the first sound of this picture.
- Show me all the pictures that start with the /s/ sound.
- Show me all pictures which have the /s/ sound.
- Tell me how many sounds you hear in the word “pin”.

Each child responded by pointing to the pictures on the picture board or by placing blocks on all the pictures that had the target sound. For the last (segmentation) activity, the child needed to give this answer: “The word has three sounds—/p/, /i/ and /n/.” Several such pictures were pointed out, and the child had to report the number of phonemes and the names of the phonemes present in the target word.

The children were also taught rhyming words. Rhyme Bingo was used as a game activity to train the children on this skill. A board with eight pictures was placed before each child, who then had to find pictures that rhymed with the pictures on the board. For example, “‘King’ [on the board] rhymes with ‘ring’.” The pictures presented on the individual cards were placed face down in front of the board. The child was then asked to pick up the picture and say which picture it rhymed with and to place that picture on top

of the matching picture on the board. A few extra pictures that did not rhyme with the target pictures were added as distracters.

Two boards with pictures (one for the examiner and one for the child) were used during the bingo game. Distracters and rhyming pictures on individual cards were placed between both boards. The players took turns to pick up a card, and the card was given to the person possessing the picture that rhymed with it. The first member of the pair to cover all the pictures on the board was declared the winner.

#### *3.4.2.2.2 Sessions 4 to 17*

A typical session consisted of 10 minutes of tracking speech sounds using coloured blocks, 10 minutes of tracking using letter tiles, 10 minutes of reading real words and non-words and 10 minutes for learning/practising a spelling rule. Each of these activities is described below.

Once the children had been taught the various phonemes and sounds present in the English language, the next step was to train them to track speech sounds. This process formed the bulk of the training sessions, and was initially conducted with the use of coloured blocks. During the activity, each child was presented with three different sounds, for example- the child was given a non-word such as “vot”. He or she was asked to identify the number of sounds and to use the coloured blocks to represent the sounds heard in this word. Once the child was proficient with this, one sound from the initial word was changed, and the child was asked to identify which sound had changed and to represent this by changing the colour of the block that represented the sound that had changed. Here is an example of this procedure.

- For *vot*, the child placed three coloured blocks to represent /v/ /o/ /t /.

- On presentation of the next sound—*lot*—the child changed the first block to a different colour and said, “The first sound changed.”
- On presentation of the next sound—*let*—the child changed the middle block and reported that the middle sound had changed.

During each session the children were able to practise three lists, each containing 10 words (an example list of words is presented in Appendix 3). The target words differed in their difficulty levels for the children, depending on the children’s basal levels and the success they had experienced in the previous sessions.

Word chains started with two sounds (vowel–consonant/or consonant–vowel combinations) and gradually progressed to chains of four and five sounds (consonant–consonant–vowel–consonant–consonant). This activity also involved simultaneous use of letter tiles. Instead of using coloured blocks, the children picked up letters to spell the word they heard. Depending upon the target list, consonants, vowels, vowel blends and consonant blends were placed before each child. Only target letters used in the training list were placed before the children, but some non-target letters were also set before them to act as distracters.

During these sessions, two other activities were carried out: (i) reading of real words and non-words; and (ii) learning/practising a spelling rule. These activities saw the children presented with a list of five real words and five non-words on cards. The children were asked to read the words using their knowledge of letter–sound relationships, gained from their learning during the programme. The words presented during each session depended on the rules taught in previous sessions. For example, if the



previous session had focused on short vowel sounds, then the list of real words and non-words consisted of short vowel sounds only.

Spelling rules were taught one at a time. During the session when the rule was taught, examples of words employing the particular spelling rule were presented to the children several times over to reinforce the rule and the children could also engage in several practice trails. During the subsequent sessions, the children were again given opportunity to practise the spelling rule relative to all games and activities being used. For example, if the rule for long vowel sounds was taught in Session 5, Session 6 included a game (memory) that required the children to match two words with the same long vowel sound (e.g., *cake* matches with *wake* but not with *bike*).

Once a child had learned two long vowel sounds for the same vowel, he or she was asked to play the same game, matching two different ways of spelling the same word (*peel* will form a pair with *peal*, *bote* with *boat*, etc). Games, activities and flash cards were used for these two activities. Once the child was noticed to be able to accurately state and identify words using one spelling rule, the child was introduced to the next rule.

Towards the end of this series of sessions, words and rules involving phonemes were replaced with activities targeting skills hypothesised to be aimed at the syllable levels.

#### 3.4.2.2.3 Sessions 18 to 20

The skills learned during the entire length of the training programme were reinforced and revised during the last three sessions. The session plan remained similar to the previous sessions and employed similar activities. However, instead of new rules being taught, old ones were revised. The older children were given writing practice that involved

constructing sentences using words and spelling rules taught in the programme. The activities contained words that mixed the spelling rules, thereby giving the children opportunity to attempt to detect the spelling rule in use in each word.

#### **3.4.2.3 Post-intervention assessment**

The post-intervention assessment was carried out on each child individually in the week following the intervention. All the assessment sessions were videotaped for later verification. During the post-treatment assessment, the children were once again assessed on all the neuropsychological tests and phonological tests in addition to the Beck's Inventory and the reading and spelling test from the NIMHANS SLD index.

### **3.5 TREATMENT FIDELITY AND ASSESSMENT RELIABILITY**

The pre-treatment assessments, the intervention, and the post-intervention assessments were all carried out by the author in order to ensure uniformity of these processes. The author was experienced in test and intervention administration and had previously observed the implementation of the Gillon and Dodd (1997) and Gillon (2000) interventions in New Zealand. The phonological awareness intervention was carried out as per the instructions and the procedure set down in the treatment manual. The author also viewed training videotapes to ensure that programme was implemented in accordance with the instructions provided in the training manual. Because this treatment was based on a pre-existing method, a "manualised" treatment approach was used.

The activities for the neuropsychological intervention were developed as part of this study. The same tasks were uniformly given to all the children in the group, and all tasks described were given to all children. Only the level of difficulty varied in line with

each child's baseline performance and his or her ability to reach saturation level on the task.

To ensure that the assessment, scoring and interventions were carried out in an unbiased manner, all assessment and 30% of the intervention sessions (i.e., every third session leading to a total of seven sessions) were videotaped. The author established a treatment protocol for each session and detailed the tasks that would be implemented. An independent examiner was provided with the protocol of what was expected in each intervention session and was required to validate, from the video-recording, that these activities had been observed. The independent rater for the two intervention programmes was a trained speech therapist and a Ph D. scholar at the Department of Communication Disorders, University of Canterbury, Christchurch, New Zealand. The rater was blind to the nature of the study but was well versed in research methodology and phonological awareness intervention. There was 100% agreement between the independent examiner's record of activities implemented in the observed session and those recorded against the treatment protocol for the session.

The scoring for the assessments was checked by another independent observer after completion of the interventions. This was done to ensure that a standardised method of scoring had been followed and that there were no errors in the scoring and interpretations of the scores. The independent observer was a Ph D scholar from the Department of Psychology, Bangalore University, Bangalore, India. The observer was an M. Phil degree holder (trained in clinical psychology and neuropsychology) and was well versed with neuropsychological testing procedures in addition to clinical practices and research methodology. However the observer was blind to the nature of the study and the

participants. The scoring of the author and the independent observer matched about 95% of the time. Any differences found between the examiner's and the author's scores were resolved via discussion and rechecking of video and/or audio analysis.

The next section presents the results of the study.

### **3.6 RESULTS**

The first purpose of the study was to identify neuropsychological and phonological awareness deficits in a group of children with specific reading disorder who were being educated in a major city in India, and to examine the deficits profile against the deficits profile of a group of 20 control group children with average reading skills. The second purpose of the study was to explore the effect of treatment on these deficits (both neuropsychological and phonological) by randomly assigning all participating children to either 20 hours of phonological awareness intervention or 20 hours of neuropsychological intervention.

Analysis involved descriptive statistical analysis. Results on continuous measurements were presented as  $X \pm SD$  (min–max); results on categorical measurements were presented in numeric form (%). Significance was assessed at the 5% level of significance. Student *t*-tests (two-tailed, independent) were used to find the significance of mean scores of study variables between the control and experimental groups and also to find the homogeneity of samples selected in the NP group and the PA group (pre-assessment). Student *t*-tests (two-tailed, dependent) were used to find the significance of study variables between the pre- and post-assessments for the NP group and then the PA group.

Effect sizes were computed to assess the extent to which the RD group differed from the NC group at the time of the pre-intervention assessment. Gain scores from pre-intervention to post-intervention were also used, and the effect sizes for these were calculated to assess the effect of intervention on the two groups of children with specific reading disorder. Effect sizes or Cohen's *d* score were interpreted based on the following break-up: a score of  $< 0.20$  was considered as no effect;  $0.20-0.50$  was considered as a mild/small effect;  $0.50 < 0.80$  as a moderate effect;  $0.80 < 1.20$  as a large effect; and  $> 1.20$  was considered to be a very large effect.

The statistical software used to analyse the data were SPSS 15.0, Stata 8.0, MedCalc 9.0.1, and Systat 11.0. Microsoft Word and Excel was used to generate tables and figures.

### **3.6.1 Comparison of the Treatment and Control Groups at Pre-Intervention**

#### **3.6.1.1 Neuropsychological test measures**

The treatment (RD) and control (NC) groups were comparable on only a few measures (Table 3.5). These measures included spatial span forward, backward, delayed recall on the Complex Figure Test, and the number of words recalled on the last trial of AVLT. The control group scored higher than the treatment group on all the other neuropsychological measures.

Significant differences were obtained on the following:

- *Visual scanning* (Colour Trail A: NC group  $X = 76.85$ ,  $SD = 23.5$ ; RD group  $X = 104.45$ ,  $SD = 31.4$ ;  $p = 0.011$ ).

- *Set-shifting abilities* (Colour Trail B: NC group  $X = 133.85$ ,  $SD = 38.0$ ; RD group  $X = 173.00$ ,  $SD = 61.1$ ;  $p = 0.018$ ).
- Word reading (Stroop Colour-Word Reading Test: NC group  $X = 78.40$ ,  $SD = 13.5$ ; RD group  $X = 59.80$ ,  $SD = 14.9$ ;  $p < 0.001$ ).
- Interference control (Stroop Colour-Word Test, colour-word reading: NC group  $X = 28.30$ ,  $SD = 5.3$ ; RD group mean = 23.40;  $SD = 6.4$ ;  $p = 0.012$ ).

A trend towards significance was noticed on tests such as colour reading on the Stroop Colour-Word Test (NC group  $X = 51.90$ ,  $SD = 8.7$ ; RD group  $X = 46.60$ ,  $SD = 9.9$ ;  $p = 0.079$ ) and visuo-perceptual abilities on copy trial of the Complex Figure Test (NC group  $X = 34.68$ ,  $SD = 1.4$ ; RD group  $X = 33.63$ ;  $SD = 1.9$ ;  $p = 0.053$ ).

### 3.6.1.2 Phonological awareness measures

The RD and NC groups were assessed on a number of phonological awareness measures. For the control group, assessment included only the Queensland University Inventory of Literacy (QUIL). For the 20 children in the RD group, the phonological awareness assessment included QUIL, non-word reading, tracking speech sounds using blocks and tiles, and the Stahl and Murray Non-word Reading Test.

Table 3.6 compares the control group (NC) and the treatment (RD) group on the QUIL. The scores indicate that the NC group and the RD group were comparable on syllable segmentation (NC group  $X = 8.25$ ,  $SD = 3.1$ ; RD group  $X = 8.0$ ,  $SD = 2.9$ ). On all other measures of phonological awareness, the two groups showed significant differences ( $p < 0.001$ ), with the performance of children with reading disorder being significantly lower than that of the normal control group.

### **3.6.3 Effect of Phonological Awareness Intervention**

The PA group was assessed on neuropsychological and phonological measures before and after intervention. The scores of the two assessments were compared using the paired *t*-test; the *p* values of the *t*-test appear in Tables 3.9 and 3.10. Effect size was calculated by comparing the change from the pre-intervention scores to the post-intervention scores. The tables show the comparison of the pre- to post-intervention measures on neuropsychological tests and phonological tests respectively for the PA group.

Table 3.5: Comparison of the normal control and reading disorder groups on neuropsychological measures

Neuropsychological test measures	NC group		RD group		<i>p</i> -value	Effect size ( <i>d</i> )
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>		
Digit forward	8.45	1.9	8.00	1.7	0.445	0.24(S)
Digit backward	5.25	1.3	4.45	1.7	0.102	0.52(M)
Digit span	9.60	1.4	9.15	1.8	0.389	0.27(S)
Spatial forward	7.80	1.8	7.75	1.7	0.929	0.03(N)
Spatial series	6.75	2.1	6.50	2.0	0.701	0.12(N)
Spatial span	15.40	22.8	10.40	1.8	0.334	0.30(S)
Fluency Trial 1	7.50	2.7	6.70	2.4	0.331	0.30(S)
Fluency Trial 2	6.70	2.4	6.00	2.8	0.406	0.26(S)
Fluency Trial 3	8.30	2.7	7.50	2.9	0.378	0.28(S)
Fluency average score	8.07	2.0	7.27	2.9	0.325	0.31(S)
Colour Trail A (CTA)	76.85	23.5	100.45	31.4	0.011*	0.83(L)
Colour Trail B (CTB)	133.15	38.0	173.00	61.1	0.018*	0.77(M)
Stroop Word Reading	78.40	13.5	59.80	14.9	<0.001**	1.28(VL)
Stroop Colour Reading	51.90	8.7	46.60	9.9	0.079+	0.56(M)
Stroop Colour & Word	28.30	5.3	23.40	6.4	0.012*	0.82(L)
Verbal Learning-1	6.80	1.3	6.35	2.2	0.435	0.24(S)
Verbal Learning-2	9.55	2.0	8.10	3.0	0.079+	0.56(M)
Verbal Learning-3	10.65	1.9	10.00	2.0	0.299	0.33(S)
Verbal Learning-4	12.20	1.1	11.40	2.3	0.163	0.44(S)
Verbal Learning-5	11.85	1.4	11.70	2.1	0.793	0.08(N)
Verbal Learning-total	51.05	5.1	47.45	9.5	0.144	0.46(S)
Verbal Memory-Imm	10.45	1.7	9.80	2.8	0.385	0.27(S)
Verbal Memory-delayed	11.10	1.4	10.40	3.2	0.383	0.27(S)
Complex Figure-copy	34.68	1.4	33.63	1.9	0.053+	0.62(M)
Complex Figure-imm	24.65	6.6	22.45	7.9	0.344	0.30(S)
Complex Figure-delayed	25.10	6.2	23.88	6.8	0.555	0.18(N)
Block Design	24.60	10.3	21.35	8.6	0.287	0.33(S)

Note: Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect



Table 3.6: Phonological awareness measures of normal control and reading disorder groups

Phonological awareness measures	NC group		RD group		p-value	Effect size (d)
	X	SD	X	SD		
Non-word reading	11.85	5.7	3.60	3.4	<0.001**	1.72(VL)
Syllable identification	11.45	0.9	9.80	2.1	0.002**	1.01(L)
Spoke rhyme	8.30	2.4	7.20	2.3	0.143	0.46(S)
Visual rhyming	5.60	1.7	4.60	1.7	0.073+	0.57(M)
Spoonerism	11.00	5.2	4.50	5.2	<0.001**	1.22(VL)
Phoneme detection	8.80	1.6	7.00	2.7	0.014*	0.80(L)
Phoneme segmentation	4.55	2.8	5.00	1.7	0.249	0.36(S)
Phoneme deletion	6.60	2.1	3.10	2.6	<0.001**	1.44(VL)

Notes: +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

### 3.6.2 Comparison of PA group and NP group

#### 3.6.2.1 Neuropsychological measures before intervention

The two treatment groups were comparable with regard to their socio-demographic status and reading difficulties before the onset of intervention. In addition to the screening measures, they were assessed on neuropsychological tests. Table 3.7 shows the neuropsychological test scores of both intervention groups before intervention. Both groups were comparable on most measures, except the digit span test. This test consists of digit forward, digit backward and total digit span. The two groups were comparable on the digit forward subtest but differed significantly on the digit backward (NP group  $X = 3.60$ ,  $SD = 1.4$ ; PA group  $X = 5.30$ ,  $SD = 1.6$ ;  $p = 0.021$ ) and on digit span (NP group  $X = 8.10$ ,  $SD = 1.4$ ; PA group  $X = 10.20$ ,  $SD = 1.5$ ;  $p = 0.006$ ). The PA group had higher scores compared to the NP group on these two measures. On all other neuropsychological measures, the two groups did not differ significantly, suggesting that they were comparable to each other on the neuropsychological measures.

Table 3.7: Comparison of the two intervention groups on neuropsychological measures before intervention

Neurological test measures	NP-pre		PA-pre		p-value
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>	
Digit forward	7.40	1.4	8.60	1.9	0.128
Digit backward	3.60	1.4	5.30	1.6	0.021*
Digit span	8.10	1.4	10.20	1.5	0.006**
Spatial forward	7.00	1.2	8.50	1.9	0.069
Spatial backward	6.20	2.0	6.80	1.9	0.509
Spatial span	9.90	1.9	10.90	1.6	0.220
Fluency Trial 1	6.90	2.6	6.50	2.2	0.719
Fluency Trial 2	6.10	1.8	5.90	3.7	0.879
Fluency Trial 3	7.30	2.9	7.70	3.1	0.769
Average score	7.83	3.3	6.70	2.6	0.402
Colour Trail A (CTA)	99.40	31.0	101.50	33.5	0.886
Colour Trail B (CTB)	178.50	78.7	167.50	40.1	0.698
Stroop Word	57.30	12.9	62.30	17.0	0.469
Stroop Colour	43.60	7.4	49.60	11.5	0.181
Stroop Colour & Word	21.90	4.8	24.90	7.6	0.305
Verbal Learning-1	5.70	1.8	7.00	2.4	0.195
Verbal Learning-2	7.20	3.3	9.00	2.6	0.188
Verbal Learning-3	9.40	1.8	10.60	2.1	0.181
Verbal Learning-4	10.60	2.5	12.20	1.8	0.119
Verbal Learning-5	11.20	2.7	12.20	1.2	0.301
Verbal Learning-total	43.90	10.3	51.00	7.5	0.095
Verbal Memory-imm	9.00	3.4	10.60	2.0	0.213
Verbal Memory-delayed	9.10	3.8	11.70	2.1	0.071
Complex Figure-copy	33.05	2.3	34.20	1.2	0.182
Complex Figure-imm	23.50	6.8	21.40	9.1	0.567
Complex Figure-delayed	24.85	7.2	22.90	6.6	0.537
Block Design	21.00	9.7	21.70	7.9	0.862

Notes: +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

### 3.6.2.2 Phonological awareness measures

The phonological measures consisted of QUIL, Sthal and Murray non-word reading and real word spelling. In addition, probes for tracking speech sounds using coloured blocks and letter tiles were used to assess phonological awareness in the two treatment groups before and after intervention. Table 3.8 shows the scores of the two groups on these measures before intervention. The two groups did not differ significantly on most of the phonological awareness measures except on spoonerism (NP group  $X = 1.40$ ,  $SD = 1.4$ ; PA group  $X = 7.60$ ,  $SD = 5.6$ ;  $p = 0.005$ ) and tracking speech trials using coloured blocks- CVC trial (NP group  $X = 2.60$ ,  $SD = 3.0$ ; PA group  $X = 6.50$ ,  $SD = 2.4$ ;  $p = 0.005$ ) where the PA group scored significantly higher than the NP group.

### 3.6.3 Effect of Phonological Awareness Intervention

Table 3.10 shows the effects of phonological awareness intervention on phonological test scores. The PA group showed a significant increase in their post-intervention performance on spoonerism ( $t(9) = 0.415$ ;  $p = 0.685$ ), phoneme deletion ( $t(9) = 6.41$ ;  $p = 0.001$ ;  $d = 2.03$ ), and tracking speech sounds using coloured blocks (CVC, CCV and CVCC patterns), with very large effect sizes for the CCV and CVCC trials and a large effect size for the CVC trial.

The PA group also showed a significant increase in tracking speech sounds using letter tile (CVCC trials:  $t(9) = 5.09$ ;  $p = 0.001$ ;  $d = 1.61$ ), reading ( $t(9) = 4.28$ ;  $p = 0.002$ ;  $d = 1.35$ ), and spelling ( $t(9) = 26.64$ ;  $p < 0.001$ ;  $d = 8.41$ ). Medium to large effect sizes were seen for non-word spelling ( $t(9) = 1.89$ ;  $p = 0.09$ ;  $d = 0.63$ ) and

Table 3.8: Comparing the two intervention groups on phonological measures before intervention

Phonological awareness measures	NP-pre		PA-pre		p-value
	X	SD	X	SD	
QNWS	4.70	1.7	5.30	2.4	0.528
QNWR	3.00	3.1	4.20	3.8	0.448
QSI	9.80	2.1	9.80	2.1	1.000
QSS	8.10	2.5	7.90	3.4	0.882
QSR	6.00	1.1	8.40	2.5	0.013
QVR	3.90	1.7	5.30	1.5	0.069
Spoonerism	1.40	1.4	7.60	5.9	0.005*
QPD	6.10	2.4	7.90	2.8	0.136
QPS	5.30	1.3	4.70	2.0	0.441
QPDI	2.70	2.8	3.50	2.5	0.509
SpellN	7.90	3.9	10.30	4.2	0.200
SpellPh	58.20	7.9	62.30	10.6	0.340
Blocks-CVC	2.60	3.0	6.50	2.4	0.005*
Blocks-CCV	2.10	2.0	3.70	2.8	0.163
Blocks-CVCC	2.20	2.7	4.40	2.9	0.097
Tiles-CVC	9.40	3.7	9.90	2.3	0.718
Tiles-CCV	0.60	1.1	1.00	1.9	0.576
Tiles-CVCC	2.10	2.7	1.30	2.1	0.464

Notes: +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$

QNWS = non-word spelling; QNWR = non-word reading; QSI = syllable identification; SS = syllable segmentation; QSR = spoken rhyming; QVR = visual rhyme; QPD = phoneme detection; QPS = phoneme segmentation; QPDI = phoneme deletion; SpellN = number of words correctly spelt; SpellPh = number of phonemes correctly spelt; CVC = consonant-vowel-consonant; CCV = consonant-consonant-vowel; CVCC = consonant-vowel-consonant-consonant

syllable segmentation ( $t(9) = 0.069$ ;  $p = 0.94$ ;  $d = 0.94$ ). Although most of the other phonological parameters showed an increase at the time of the post-intervention assessment, they failed to reach statistical significance.

On the neuropsychological measures, the PA performance improved significantly after intervention on verbal fluency Trial 1 ( $t(9) = 1.5$ ;  $p = 0.003$ ;  $d = 0.82$ ), visual scanning on Colour Trail A ( $t(9) = 2.42$ ;  $p = 0.039$ ;  $d = 0.76$ ), Stroop Colour Reading

( $t(9) = 4.29$ ;  $p = 0.002$ ;  $d = 1.36$ ), verbal learning on the second trial of the Auditory Verbal Learning Test (AVLT 2:  $t(9) = 3.29$ ;  $p = 0.009$ ;  $d = 1.11$ ), Trial 5 of AVLT ( $t(9) = 6.13$ ;  $p < 0.001$ ;  $d = 0.79$ ), immediate visual memory (CFT I:  $t(9) = 2.72$   $p = 0.023$ ;  $d = 1.11$ ), delayed recall on visual memory test (CFT D:  $t(9) = 2.59$ ;  $p = 0.029$ ;  $d = 0.82$ ), and Block Design ( $t(9) = 3.63$ ;  $p = 0.018$ ;  $d = 1.86$ ).

A medium effect size was seen for scores on spatial span ( $t(9) = 1.5$ ;  $p = 0.17$ ;  $d = 0.56$ ) and total learning on the verbal learning test (AVLT-total:  $t(9) = 2.49$ ;  $p = 0.04$ ;  $d = 0.79$ ).

### **3.6.4 Effect of Neuropsychological Intervention**

The neuropsychological intervention provided training to enhance attention, memory, planning and organisation, working memory and continuous tracking of phonemes. The group was assessed on neuropsychological and phonological awareness tests before intervention and after intervention.

The effect of treatment was measured as effect sizes of the difference from pre- to post-treatment scores on the various assessments. In addition  $t$  scores and the  $p$  values are reported in Tables 3.11 and 3.12 below. Table 3.11 shows the pre- and post-intervention scores on the neuropsychological tests while Table 3.12 shows the pre- and post-phonological awareness scores for the NP group.

*Table 3.9: Effect of phonological awareness intervention on neuropsychological measures*

<i>Neurological test measures</i>	<i>PA-pre</i>		<i>PA-post</i>		<i>p-value</i>	<i>Effect size(d)</i> <i>(pre-post diff)</i>
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>		
Digit forward	8.60	1.9	8.00	2.3	0.357	0.31(S)
Digit backward	5.30	1.6	5.70	1.6	0.423	0.26(S)
Digit span	10.20	1.5	9.60	2.0	0.297	0.50(S)
Spatial forward	8.50	1.9	8.70	1.5	0.678	0.06
Spatial backward	6.80	1.9	7.70	1.6	0.235	0.11
Spatial span	10.90	1.6	11.50	1.4	0.168	0.56(M)
Fluency Trial 1	6.50	2.2	8.40	2.3	0.030*	0.82(L)
Fluency Trial 2	5.90	3.7	6.80	3.6	0.287	0.63(M)
Fluency Trial 3	7.70	3.1	7.60	3.8	0.916	0.29(S)
Fluency average	6.70	2.6	7.60	2.8	0.07+	0.63(M)
Colour Trail A (CTA)	101.50	33.5	75.60	21.0	0.039*	0.76(M)
Colour Trail B (CTB)	167.50	40.1	153.30	44.3	0.516	0.27(S)
Stroop Word	62.30	17.0	68.50	16.4	0.069+	0.65(M)
Stroop Colour	49.60	11.5	49.20	20.2	0.941	1.36(VL)
Stroop Colour & Word	24.90	7.6	27.40	5.8	0.248	0.39(S)
Verbal Learning-1	7.00	2.4	8.70	2.3	0.152	0.50(S)
Verbal Learning-2	9.00	2.6	10.70	2.0	0.009**	1.11(L)
Verbal Learning-3	10.60	2.1	11.20	2.7	0.475	0.65(M)
Verbal Learning-4	12.20	1.8	12.70	1.8	0.440	0.26(S)
Verbal Learning-5	12.20	1.2	13.30	1.2	<0.001**	1.93(VL)
Verbal Learning-total	51.00	7.5	56.20	7.3	0.035	0.79(M)
Verbal Memory-imm	10.60	2.0	11.70	2.5	0.343	0.32(S)
Verbal Memory-delayed	11.70	2.1	12.30	1.8	0.483	0.23(S)
Complex Figure-copy	34.20	1.2	32.60	4.3	0.235	0.29(S)
Complex Figure-imm	21.40	9.1	27.50	5.9	0.023*	1.11(L)
Complex Figure- delayed	22.90	6.6	27.65	5.5	0.029*	0.82(L)
Block Design	21.70	7.9	33.70	9.0	0.005**	1.86(VL)

*Notes:* +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$ ;

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

Table 3.10: Effect of phonological awareness intervention on phonological measures

Phonological awareness measures	PA-pre		PA-post		p-value	Effect size(d) (Pre-post diff)
	X	SD	X	SD		
QNWS	5.30	2.4	6.90	3.8	0.091+	0.63(M)
QNWR	4.20	3.8	7.70	6.7	0.164	0.48(S)
QSI	9.80	2.1	8.20	4.9	0.345	0.32(S)
QSS	7.90	3.4	7.80	2.4	0.946	0.94(L)
QSR	8.40	2.5	7.80	1.8	0.443	0.25(S)
QVR	5.30	1.5	5.20	2.4	0.904	0.04
QSpoon	7.60	5.9	9.50	5.6	0.136	0.04
QPD	7.90	2.8	8.90	2.8	0.052+	0.50(M)
QPS	4.70	2.0	7.60	3.1	0.033*	0.30(S)
QPDI	3.50	2.5	6.00	3.4	0.024*	2.03(VL)
SpellN	10.30	4.2	10.70	3.4	0.479	8.42(VL)
SpellPh	62.30	10.6	62.50	8.5	0.942	0.03
TSSB-CVC	6.50	2.4	9.30	1.7	0.010**	1.02(L)
TSSB-CCV	3.70	2.8	9.80	1.3	0.001**	1.23(VL)
TSSB-CVCC	4.40	2.9	10.10	1.2	<0.001**	1.85(VL)
TSST-CVC	9.90	2.3	9.60	2.3	0.763	0.09
TSST-CCV	1.00	1.9	4.10	4.1	0.060+	0.66(M)
TSSB-CVC	1.30	2.1	7.70	3.5	0.001**	1.61(L)
Reading	383.00	158.3	488.60	117.0	0.002**	1.35(VL)

Notes: +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

QNWS = non-word spelling; QNWR = non-word reading; QSI = syllable identification; QSS = syllable segmentation; QSR spoken rhyme; QVR = visual rhyme; QPD = phoneme detection; QPS = phoneme segmentation; QSpoon = spoonerism; QPDI = phoneme deletion; SpellN = number of words correctly spelt; SpellPh = number of phonemes correctly spelt; CVC = consonant–vowel–consonant; CCV = consonant–consonant–vowel; CVCC = consonant–vowel–consonant–consonant.

### 3.6.4.1 Neuropsychological functioning of the NP group

The NP group made significant gains in neuropsychological functions and phonological awareness after the intervention. Table 3.11 shows the group scores after intervention.

Significant increases were noticed on two of the three trials of verbal fluency (Trial 1:

$t(9) = 5.91, p < 0.001, d = 2.75$ ), (Trial 2:  $t(9) = 1.95; p = 0.083; d = 1.06$ ), (Trial 3:  $t(9) = 3.61, p = 0.006, d = 1.19$ ).

Significant increases also emerged for Stroop word reading ( $t(9) = 2.23, p = 0.053, d = 0.74$ ), colour reading ( $t(9) = 3.24, p = 0.010, d = 1.18$ ), and colour-word reading ( $t(9) = 2.81, p = 0.02, d = 0.89$ ). The same applied to immediate visual memory (CFTI:  $t(9) = 2.57, p = 0.030, d = 1.09$ ] and visuo-construction abilities on Block Design ( $t(9) = 2.95, p = 0.018; d = 0.84$ ). A trend towards significance was noticed on total learning on verbal learning (AVLT total:  $t(9) = 1.93, p = 0.08, d = 0.59$ ).

### 3.6.4.2 Phonological awareness measures

Improvements on phonological awareness measures were also evident for the NP group. These results are reported in Table 3.12. Significant changes were seen in the phonological profile of this group both at the phoneme level and at the syllable level. Very significant differences were seen on tracking of speech sounds using blocks (CCV:  $t(9) = 4.26, p = 0.002, d = 1.34$ ; CCVC:  $t(9) = 2.37, p = 0.042, d = 0.69$ ) at the phoneme level.

At the syllable level, spoonerism ( $t(9) = 3.91, p = 0.004, d = 1.24$ ) and visual rhyme ( $t(9) = 2.86, p = 0.019, d = 0.52$ ) showed significant changes. A trend towards significance was evident for syllable identification ( $t(9) = 2.19, p = 0.057, d = 0.72$ ), spoken rhyme ( $t(9) = 2.21, p = 0.0063, d = 0.67$ ), phoneme detection ( $t(9) = 1.99, p = 0.077, d = 0.51$ ), and tracking changes in syllables using blocks (TSSB-CVC:  $t(9) = 0.93, p = 0.086, d = 0.88$ ). Reading scores improved significantly after the intervention ( $t(9) = 2.87, p = 0.018, d = 1.04$ ).



Table 3.11: Effect of neuropsychological intervention on neuropsychological measures

Neurological test measures	NP-pre		NP-post		p-value	Effect size(d)
	X	SD	X	SD		
Digit forward	7.40	1.4	8.20	2.1	0.269	0.49 (S)
Digit backward	3.60	1.4	4.00	1.3	0.494	0.23 (S)
Digit span	8.10	1.4	9.20	2.2	0.178	0.68(M)
Spatial forward	7.00	1.2	7.90	2.8	0.262	0.53(M)
Spatial backward	6.20	2.0	6.20	1.5	1.000	-
Spatial span	9.90	1.9	10.00	1.4	0.758	0.32(S)
Fluency Trial 1	6.90	2.6	11.50	2.3	<0.001**	2.73(VL)
Fluency Trial 2	6.10	1.8	7.70	2.7	0.083+	1.06(L)
Fluency Trial 3	7.30	2.9	12.90	5.2	0.006**	1.19(L)
Fluency average	7.83	3.3	10.54	2.9	0.094+	1.89(VL)
Colour Trail A (CTA)	99.40	31.0	92.40	29.5	0.452	0.39(S)
Colour Trail B (CTB)	178.50	78.7	178.20	67.1	0.978	0.23(S)
Stroop Word	57.30	12.9	63.10	15.1	0.053+	0.74(M)
Stroop Colour	43.60	7.4	49.90	7.3	0.010**	1.18(L)
Stroop Colour & Word	21.90	4.8	26.20	4.3	0.020*	0.89(L)
Verbal Learning-1	5.70	1.8	6.70	2.9	0.221	0.43(M)
Verbal Learning-2	7.20	3.3	9.20	3.5	0.123	0.62(M)
Verbal Learning-3	9.40	1.8	10.90	2.1	0.096+	0.68(M)
Verbal Learning-4	10.60	2.5	11.70	1.3	0.207	0.54(M)
Verbal Learning-5	11.20	2.7	11.90	2.6	0.466	0.20(S)
Verbal Learning-total	43.90	10.3	50.40	10.9	0.086+	0.59(M)
Verbal Memory-imm	9.00	3.4	10.80	2.7	0.177	0.59 (M)
Verbal Memory-delayed	9.10	3.8	11.40	2.1	0.100	0.67(M)
Complex Figure-copy	33.05	2.3	34.00	2.3	0.227	0.56(M)
Complex Figure- imm	23.50	6.8	27.10	5.0	0.030*	1.09(L)
Complex Figure-delayed	24.85	7.2	26.50	5.5	0.157	0.57(M)
Block Design	21.00	9.7	28.50	8.3	0.016*	0.84(L)

Notes: + 0.05 < p < 0.10; \* 0.01 < p ≤ 0.05; \*\* p ≤ 0.01

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

Table 3.12: Effect of neuropsychological intervention on phonological awareness

Phonological awareness measures	NP-pre		NP-post		p-value	Effect size(d) (pre-post diff)
	X	SD	X	SD		
Non-word spelling	4.70	1.7	5.60	3.3	0.317	0.63(M)
Non-word reading	3.00	3.1	5.40	4.1	0.132	0.91(L)
Syllable identification	9.80	2.1	12.20	3.2	0.057+	0.72(M)
Syllable segmentation	8.10	2.5	8.10	2.0	1.000	0.12
Spoken rhyme	6.00	1.1	7.00	1.6	0.063+	0.67(M)
Visual rhyming	3.90	1.7	4.80	1.5	0.019*	0.52(M)
Spoonerism	1.40	1.4	5.50	4.2	0.004**	1.24(VL)
Phoneme detection	6.10	2.4	7.40	1.6	0.077+	0.51(M)
Phoneme segmentation	5.30	1.3	5.00	2.7	0.785	0.06
Phoneme deletion	2.70	2.8	4.40	2.2	0.028*	1.0
SpellN	7.90	3.9	9.00	2.7	0.102	0.88(L)
SpellPh	58.20	7.9	60.70	8.6	0.500	0.16
TSSB-CVC	2.60	3.0	4.90	3.1	0.086+	0.88(L)
TSSB-CCV	2.10	2.0	5.70	2.5	0.002**	1.34(VL)
TSSB-CVCC	2.20	2.7	5.20	2.7	0.042*	0.69(M)
TSST-CVC	9.40	3.7	9.78	3.7	0.779	0.10(N)
TSST-CCV	0.60	1.1	0.30	0.9	0.193	0.32(S)
TSSB-CVCC	2.10	2.7	3.30	3.2	0.367	0.36(S)
Reading	346.00	144.9	437.60	126.3	0.018*	1.04(L)

Notes: +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

SpellN= number of words correctly spelt; SpellPh= number of phonemes correctly spelt; CVC = consonant-vowel-consonant; CCV = consonant-consonant-vowel; CVCC= consonant-vowel-consonant-consonant

### 3.6.5 Comparison of the PA and NP Groups after Intervention

Before the intervention, the two groups were comparable on neuropsychological measures except for digit backward and digit span. On these two measures, the PA group scored significantly higher than the NP group. Post-intervention assessment revealed that the two groups significantly differed on a few more measures. The PA group scored significantly higher on digit backward ( $t(18) = 2.613$ ;  $p = 0.018$ ), spatial span backward

( $t(18) = 2.153$ ;  $p = 0.045$ ) and spatial span total ( $t(18) = 2.355$ ;  $p = 0.030$ ). The NP group scored significantly higher than the PA group on verbal fluency ( $t(18) = 2.303$ ;  $p = 0.033$ ). The two groups were comparable on all other neuropsychological measures. They did not differ significantly on any of the phonological awareness measures. Their reading scores were also comparable.

### **3.6.6 Effect of Intervention on Emotional Wellbeing**

The two treatment groups were assessed on the Beck Youth Inventory of Social and Emotional Impairment. The inventory consists of five subscales that assess self-concept, anxiety, depression, anger, and disruptive behaviour. The two treatment groups were asked to rate themselves on the five subscales both before and after the intervention.

Before intervention, the PA group scored significantly higher than the NP group on self-concept and depression while the NP group scored higher on the anxiety subscale. Changes in the profiles on these five subscales were noticed after intervention. Table 3.13 shows the pre-post intervention comparison of the two groups on this scale. The changes noticed in the two groups were not uniform. The PA group reported an increase in their anger ( $p = 0.051$ ;  $d = 0.26$ ) and showed a significant decrease in self-concept after intervention ( $p = 0.05$ ;  $d = 0.39$ ). Before intervention, the PA group reported higher self-concept and depression while the NP group scored higher on the anxiety subscale.

The scores from before intervention to after intervention were compared for each intervention group independently. After intervention, the PA group reported a drop in self-concept score, which displayed only a trend towards significance ( $p = 0.05$ ;  $d = 0.39$ ). The NP group did not report any significant change. The NP group reported higher

disruptive behaviour after intervention. The difference between the PA group and the NP group on this subscale showed a trend towards significance ( $p = 0.07$ ;  $d = 0.09$ ]

*Table 3.13: Social-emotional measures before and after intervention*

<i>Beck scales</i>	<i>PA group</i>		<i>p-value</i>	<i>Effect size (d)</i>	<i>NP group</i>		<i>p-value</i>	<i>Effect size(d)</i>	<i>Effect size(d) (PA post–NP post)</i>
	<i>pre</i>	<i>post</i>			<i>pre</i>	<i>post</i>			
Self-concept	47.5 (5.08)	39.5 (12.24)	0.05 +	0.39(S)	41.6 (8.11)	43.7 (10.82)	0.55	0.11	0.18
Anxiety	52.10 (5.71)	54.20 (8.08)	0.51	0.15	52.70 (6.09)	49.20 (9.14)	0.39	0.22	0.28
Depression	53.30 (5.58)	54.9 (12.79)	0.72	0.08	49.3 (8.03)	46.2 (7.48)	0.41	0.20	0.38
Anger	46.50 (4.67)	50.56 (9.36)	0.23	0.26	46.80 (7.39)	45.50 (6.17)	0.74	0.20	0.30
Disruptive behr.	47.8 (6.16)	48.00 (5.98)	0.93	0.01	51.30 (9.18)	49.80 (11.59)	0.73	0.07	0.09

*Notes:* +  $0.05 < p < 0.10$ ; \*  $0.01 < p \leq 0.05$ ; \*\*  $p \leq 0.01$

Effect size: N = no effect; S = small effect; M = moderate effect; L = large effect; VL = very large effect

### 3.6.7 Summary

The results indicate that the two groups were comparable to each other before the intervention on reading ability, intellectual functioning, age and neuropsychological functioning as well as phonological awareness abilities. After intervention, the two groups showed improvement on those aspects for which they received training during the respective intervention programmes. In addition, several related functions along with reading showed improvement. Emotional and social behaviour was also influenced by the intervention despite these not being the primary target. The NP group reported a decrease in anger, anxiety and depression while the PA group reported a drop in their self-concept and an increase in anger.

### **3. 7 DISCUSSION**

The intervention study was carried out with children with reading difficulties. The aims of the study were to:

1. Identify the neuropsychological and phonological deficits in a group of children with reading difficulties;
2. Explore the effect of phonological awareness intervention on reading and on phonological awareness measures as well as on neuropsychological functioning; and
3. Explore the effects of neuropsychological intervention on reading, neuropsychological functioning and phonological processing.

#### **3.7.1 Deficits at Pre-treatment: Comparison of the Treatment Group with the Control Group**

Three component skills that are important for good readers to master are word attack, word identification and comprehension (Anderson, 2002). All of these skills rely on the child's knowledge and use of phonological information. Phonological processing skills, including phonological awareness, rapid naming, and verbal working memory, comprise the primary focus of most studies of children with reading disorders. Studies show that phonological skills are predictive of reading ability from kindergarten through the early elementary grades (Betourne & Friel-Patti, 2003). Phonological awareness skills include the ability to discriminate and generate rhyming words, segment words into phonemes, manipulate phonemes within words and identify letter-to-sound (grapheme–phoneme) relationships.

Research studies reveal that children with reading disorders have deficits in the area of phonological awareness skills (Shaywitz & Shaywitz, 2005). The results of the current study suggest that the children with reading disorders have deficits in phonological processing compared with average readers. These components include non-word reading, phoneme detection and spoonerism (phoneme manipulation task), syllable identification, phoneme detection and visual rhyme. The children with reading disorders differed on phoneme segmentation and spoken rhyme compared to average readers. No difference was found on syllable segmentation. The findings are comparable with several other studies that propose that children with reading disorder differ from age-matched average readers on phonological processing and awareness measures (see, for example, Shaywitz & Shaywitz, 2005).

Despite the popularity of the phonological deficit theory, recent studies show that some children have adequate phonological processing abilities (Castles & Coltheart, 2004) whereas other studies point to the presence in this group of deficits additional to the phonological awareness deficits. These include visual attention span (Bosse, Tainturier, & Valdois, 2007), interference control (Protopapas, Achroniti, & Skaloumbakas, 2007) and executive function deficits.

In the present study, we attempted to identify a range of neuropsychological deficits in addition to the phonological awareness deficits evident in a group of children with reading difficulty. We achieved this by assessing 20 children (age range, 10–13 years) with reading difficulty and compared their performance on a set of neuropsychological tests with a group of 20 average readers of the same age. The two groups were

comparable in terms of their age and number of years in school but differed significantly with respect to their reading skills.

On the neuropsychological tests, the two groups differed significantly on interference control (Stroop colour and colour-word trials), verbal working memory (as measured on digit backward) visual attention (Colour Trail A), set-shifting (Colour Trail B) and visual perception (Complex Figure Test-copy trial). On verbal learning and memory, visual memory (as seen on the Complex Figure Test immediate and delayed recall trials), visuo-spatial construction ability (Block Design) and verbal fluency, the difference between the RD group and the control group was not statistically significant with only small effect sizes.

The deficits described above can be grouped under executive functions. Executive functions refer to a collection of cognitive abilities, such as planning, sequencing, organisation and inhibition, possibly associated with the functioning of the prefrontal cortex (Fuster, 1989). Working memory and inhibition have been identified as the two dimensions critical for understanding the breadth of executive functioning tasks. Tasks with a high demand for either or both of these dimensions are proposed to be sensitive to prefrontal function (Robertson & Murre, 1999). Hynd et al. (1990) demonstrated that atypical symmetry of the prefrontal regions was correlated with deficits in reading skills. There is also evidence of abnormal symmetry in the prefrontal cortex in language-impaired children, in the absence of such abnormalities in more posterior areas associated with language (Galaburda, Sherman, Rosen, Aboitiz, & Geschwind, 1985).

In the present study, a large effect size was seen for the Stroop Colour-Word Test on the colour and colour-word trials. We propose that this finding aligns with the findings

of Protopapas and colleagues (2007), who reported that reading disability is negatively proportional to interference control. Interference control is taken as a measure of reading automacity, that is, both reading speed and accuracy. Protopapas et al. propose that automacity is a complex process that requires several functions such as speed, attention allocation, voluntariness and conscious awareness. The authors furthermore explain that when a skill becomes automatic, it requires less conscious intent and does not tax the available cognitive resources. When translated to skilled reading, automaticity allows a reader to read without much conscious effort, thereby leaving him or her with enough cognitive resources to allocate to understand the text. In the case of children with reading difficulties (or even with beginner readers), automacity fails to be established, thus resulting in deficits in adequate word decoding skills and, from there, understanding the text. The finding in the current study reflects this aspect, suggesting that interference control may probably be required for skilled reading. The children in the control group were significantly different from the treatment group on both reading accuracy as well as interference control, further suggesting a possible relationship between reading skill and interference control.

In the current study, the RD group significantly differed from the control group on executive functions such as interference control, visual attention and scanning, set-shifting, verbal fluency, and working memory. They also showed mild difficulties in verbal learning and memory. Working memory is another important executive function hypothesised to be associated with reading disability (Swanson, 1999). In the current study, we find a significant difference between the control group (average readers) and



the treatment (RD) group on working memory task (digit backward subtest), suggesting that the RD group presumably had impaired working memory before intervention.

On the test of verbal learning and memory, the RD group differed significantly from the control group, specifically on Trial 2. Small effect sizes were seen for all other trials except for Trial 5, where the two groups were comparable, suggesting that, despite learning fewer words initially, the RD group managed to learn as many words as the control group. However, they also forgot a greater number of words compared to the control group, indicating possible immediate and long-term memory deficits. These deficits are hypothesised to interfere with their ability to profit from repeated exposure to reading material. However, not all neuropsychological functions were impaired in the RD group. The two groups were comparable on delayed recall on CFT and spatial span forward and backward, indicating that the two groups were comparable with regard to their visual memory and visuo-spatial working memory.

To summarise, the results of the current study point towards probable deficits in inhibition, working memory, set-shifting and verbal fluency in children with reading difficulty. The findings of this study support previous findings showing the presence of cognitive deficits, outside the realm of phonological processing skills, in poor readers. Earlier studies also report the presence of executive deficits in this population (Bosse, Tainturier, & Valdois, 2007; Lazar & Frank, 1998; Protopapas, Achroni, & Skaloumbakas, 2007). Functionally, the executive functions are hypothesised to be controlled by the frontal lobes, especially the prefrontal regions of the brain. These functions are not known to be directly associated with phonological processing but are proposed to play a supportive role in processing sounds.

### **3.7.2 Effects of Phonological Awareness Intervention**

We hypothesised that the children's reading scores and phonological skills would improve after phonological intervention, and that only those cognitions that support phonological processing would improve after intervention. Research indicates that phonological processing deficits are amenable to training (Lovett & Steinbach, 1997; Shaywitz & Shaywitz, 2005). Phonological processing intervention methods have brought about changes in those neural regions associated in phonological processing abilities and in accuracy of reading and word decoding abilities. These remedial programmes, however, are not reported to affect other associated aspects, such as visual naming speed, fluency and attention, all of which are proposed to be crucial to overall improvement in disabled readers (Lovett et al., 2000).

Findings in literature also suggest that the nature of the remedial intervention is critical to successful outcomes in children with reading disabilities and that the use of an evidence-based phonological reading intervention facilitates the development of those neural systems that underlie skilled reading. The work of Shaywitz and colleagues (2004, 2005) indicates that a phonologically based reading intervention leads to the development of neural systems both in anterior (inferior frontal gyrus) and posterior (middle temporal gyrus) brain regions. Their 2004 study indicated that the nature of the intervention is crucial in bringing about changes in reading (word-decoding skills) and in the neural structures responsible for reading. Noting how reading difficulties and associated deficits improve after phonological awareness intervention is therefore of interest.

Assessment after intervention revealed that all 10 children in the phonological awareness intervention group showed improvement in their reading scores. They made

fewer errors and were able to read passages that were closer to their age/class level. Many of the children displayed an ability to correct their own errors while reading. In addition, if a word occurred more than once in a passage and the children made an error (and corrected it) the first time it appeared, they remembered to read it correctly thereafter. These behavioural changes were also reflected in the increase in their reading scores after intervention compared with their pre-treatment reading scores and the scores of age-matched average readers.

Improvement was also seen in the phonological awareness abilities. Significant changes were noticed in non-word reading and non-word spelling, phoneme segmentation and phoneme deletion and tracking speech sounds using both coloured blocks and letter tiles. These skills are hypothesised to reflect better word decoding skills. Non-word reading and spelling deficits are well known in this population (Shaywitz, 2003; Simos, Brier, & Fletcher, 2000). Accurate reading of these relies on word-decoding skills. Improvement in these skills indicated improved word-decoding skills in this group. Behavioural improvement was also evident. In addition, the PA treatment group showed significant change in their phoneme analysis and synthesis scores, such as deletion and segmentation, indicating improved ability to break up a word into its sound units and to manipulate phonemes.

The group furthermore performed better on tracking activities for which they received training during the intervention programme. However, the effects of training at this point did not show a transfer to improvement at the syllable level. Thus, the phonological awareness intervention programme improved real word reading, non-word reading and spelling abilities and improved tracking sounds and segmentation and

deletion at the phoneme level. Improvement did not include real word spelling or analysis and synthesis at the syllable level.

Effects of intervention were examined on the neuropsychological functions from pre- to post-intervention in this group. Although the members of the group did not receive training on these cognitive abilities, they showed significant improvement on visuo-spatial working memory, visual memory (as seen on CFT I and CFT D) and verbal learning and memory. Small effect sizes were noticed for verbal working memory, verbal fluency and interference control. Visual memory and verbal memory are hypothesised to be associated with the temporal and parietal lobe functions of the left hemisphere.

These regions are known to be associated with phonological processing abilities (Shaywitz & Shaywitz, 2005). The improvements in phonological awareness and neuropsychological tests point towards improvements in the anatomic regions associated with phonological processing abilities. Phonological processing abilities consist of phonological awareness, verbal naming and verbal memory. Improvements in all these aspects were found in the PA group in this study. These improvements, along with the improvement in their reading scores, are also consistent with findings from the existing literature that shows training on phonological processing abilities results in improved phonological skills as well as reading abilities. Improvements in the non-word reading and non-word spelling abilities of the group are proposed to indicate better word decoding abilities after intervention in this group .

### **3.7.3 Effects of Neuropsychological Intervention**

We hypothesised that after neuropsychological intervention, the children would exhibit improved reading scores and neuropsychological functioning. However, no change in phonological processing abilities was noticed. Before the start of the intervention, the NP group differed significantly from the control group with regard to reading, neuropsychological functioning and phonological awareness. After intervention, the NP group showed significant improvement in cognitive functions for which they received training, such as verbal fluency and interference control. Both these are hypothesised to be part of executive functions. In addition, large effect sizes were found for cognitive functions such as attention (digit forward) and verbal and visual working memory (digit span and spatial span forward series, respectively). Both attention and working memory are components of executive functions. Verbal learning and memory-immediate visual memory (CFT I) and visuo-spatial functioning (Block Design Test) also showed moderate effect sizes. We propose that taken together, these findings provide evidence of better learning and memory skills in the children's visual and verbal modalities.

According to Nobel, Tottenam and Casey (2005), three basic cognitive functions are essential in order for a child to be successful academically. These functions include cognitive control (also known as executive functioning), learning and memory and reading. Cognitive control, or executive control as it is also known, is a function of the prefrontal cortex and consists of processes such as attention, working memory and interference control. These processes develop with age, and experiences in the child's life can bring about changes in this ability. Learning and memory is another important component on which academic success depends. Learning ability is hypothesised to be controlled by the hippocampus and allows children to form associations to new

events/activities in order to be able to understand and to remember. With repeated exposure to activities, it is proposed that one is able to form better associations, which are further strengthened with the help of pre-frontal activity. Both association and ability to learn are hypothesised to increase with age, and the two abilities complement each other in their functioning.

The third important aspect of cognition in children is that of reading and its associated phonological processing abilities. These directly relate to a child's academic progress and are proposed to be controlled by the temporo-parietal and temporo-occipital regions on the left side of the brain. All three functions are known to be affected by negative life events and can improve with environmental influences (Noble et al., 2005).

Studies show specific brain-related changes after intervention for reading (Horwitz, Rumsey, & Donohue, 1998; Shaywitz et al., 2002; Simos et al., 2002; Temple et al., 2003). The findings of these studies indicate that specifically targeted inputs probably lead to improvements in specific brain functions. These improvements are hypothesised to show generalisation to day-to-day activities, thus making the training clinically relevant.

The current study further emphasized this point by showing that cognitive functions that were trained as part of the intervention programme improved and that, along with this improvement, there was a possible generalisation to associated functions such as reading and phonological skills. The NP group made significant gains not only in their reading but also in their phonological awareness at both syllable and phoneme level. Significant improvement was seen on non-word reading, non-word spelling, tracking speech sounds using coloured blocks, phoneme detection, phoneme deletion, syllable

identification, spoken and visual rhyme and spoonerism. Small effect sizes were noticed for real word spelling. The intervention programme targeted those cognitive abilities (attention, working memory, verbal fluency, organising and planning, learning and memory and continuous phoneme tracking) that are hypothesised to play a supportive role in reading and spelling.

Another interesting change noticed in the NP group after intervention concerned social and emotional functioning. The NP group compared to the PA group was significantly lower on self-concept and higher on disruptive behaviour before intervention. After intervention, the members of the NP group were comparable to the members of the PA group on self-concept and disruptive behaviour. They also showed a significant decrease in their anger, anxiety and depression. On all three core emotions assessed by the inventory, the NP group's scores differed from their pre-treatment scores and differed significantly from the scores of the PA group. Thus, we hypothesised that the intervention reduced negative emotions in the group after intervention. We hypothesised that an intervention that targets the functioning of certain anatomical regions as a whole, could probably lead to improvement in all functions controlled by that/those region(s).

The study thus provides evidence that targeting executive functions (primarily a bilateral frontal function) and verbal and visual memory (bilateral temporal function) lead to improvements in the trained cognitions, which probably generalises to reading, phonological skills and social-emotional behaviour. The programme therefore possibly targets behaviour holistically rather than to compartmentalise functions and target only some to the exclusion of other associated functions.

The findings of this study highlight two important issues. First, training programmes can improve deficit cognitive abilities by providing specific inputs over a period of time. This is evident from the significant improvements seen in the two treatment groups. The neuropsychological intervention group improved on executive functions and verbal and visual memory after intervention. The PA group also improved on phonological processing skills after the training.

The second aspect refers to the ability of a remedial programme to influence cognitive abilities other than those trained, that is, to exhibit generalisability. The significant improvements in phonological skills after a neuropsychological intervention and the significant improvement in neuropsychological skills after phonological awareness training are possible indications of generalisation. The two remedial programmes directed at improving reading by providing training skills are known to have a causal relation with reading (phonological processing skills) and to target those cognitive abilities that are required to carry out fluent reading activity (executive functions and verbal memory). Although different in their orientation to reading, both programmes showed a significant change in reading abilities. They also showed a generalising effect by influencing other associated aspects of reading.

### **3.8 IMPLICATIONS OF THE FINDINGS**

Both treatment groups differed from the control group on several aspects before intervention. After intervention, both groups showed better reading skills. Other functions improved differently for the two groups. The rate of change seen and the cognitive abilities that improved versus those that remained unchanged were also different for the



two groups. These differences in the pattern of change for the two groups can be attributed to the treatment they received. Both groups were comparable in their socio-demographic details, reading abilities and cognitive and phonological abilities. Both groups received the same number of intervention sessions spanning the same period of time. All interventions were individual sessions and differed only with regard to the tasks used. Both groups were assessed on the same set of tests before and after intervention. Because the only difference between them was the nature of the intervention provided, the change noticed after intervention could possibly be attributed to the inputs they received.

Studies using imaging techniques show that brain activation patterns can change dramatically over the course of relatively short-lived interventions (Shaywitz et al., 2002; Temple et al., 2003). Thus specifically targeted, brief intervention programmes can help reduce reading difficulties in children with reading disorder. The current study further highlights this in addition to the fact that interventions can also have a impact on associated cognitive skills.

### **3.9 LIMITATIONS OF THE STUDY**

The study has several limitations. The first is sample size: there were only 10 children in each intervention group. The small sample size limited the possibility of employing statistical procedures that would have provided better understanding of the findings of the study. Also, the population from which the sample was drawn is known to have vast individual differences in assessment and response to intervention. The small sample meant that these differences could not be accounted for or nullified.

The study was carried out on an Indian population. International assessment tools could not be used for this population because the tools have not been standardised on it, making scoring and interpretation of testing outcomes difficult. Because reading tests typically used in the West could not be used, an indigenous reading test developed for the Indian population was used. This test did not, however, give reading scores, and the presence of reading difficulty was a clinical decision rather than a statistical one. Hence, for the purpose of scoring, number of words correctly read was used instead of level of reading (as occurs clinically when diagnosing a child with reading difficulties). For assessing intelligence, a non-verbal test of intelligence alone was used. A verbal test of intelligence would have been a useful addition, while a planning test could have added another aspect to the present neuropsychological test battery.

The statistical analysis showed significant group differences at pre-treatment on behavioural and emotional scales between the two treatment groups. Parent ratings, teacher ratings and self-ratings showed that the NP children had more behavioural difficulties than the other participating children. However, the difficulties were below the cut-off on the parental interview schedule and the teacher ratings. On the self-rating scale, all scores were in the average range. Thus, despite significant differences in the two groups, their scores remained within the average range, ensuring that these differences were not clinically significant.

The repeated use of *t* tests in the analysis increased the likelihood of Type I errors. Bonferroni corrections could have been used in an attempt to control for this error. However, this was not done because of the sample size, and  $p < 0.05$  was accordingly used for interpretative purposes.

### 3.10 CONCLUSIONS

The results of the study revealed that not only phonological processing deficits are associated with reading difficulties but also neuropsychological deficits. These deficits are in the form of executive functioning and they are evident relative to learning and memory in the verbal and visual modalities.

Treatment effects of phonological processing abilities were seen in reading, phonological awareness, verbal fluency and learning and memory, findings that accord with those of several earlier studies. These studies report that phonological awareness, verbal naming speed (fluency) and verbal memory together form phonological processing abilities that influence reading abilities. Thus, improved phonological processing abilities result in improved reading.

The neuropsychological training intervention endeavoured to improve those cognitions not directly associated with reading but known to play a supportive role in the reading process. This study findings show that training on those basic cognitions leads to improved reading abilities for children with reading difficulties. Phonological awareness skills also showed improvement despite these aspects not being included in the neuropsychological intervention. Thus, training on neuropsychological functions also has an impact on reading and phonological abilities.

The post-intervention assessments were carried out immediately after the intervention programme. The improvements noticed in the two groups were significant in several domains of cognition and reading. For a programme to be considered successful, the gains made by the treatment groups need be maintained over a period of time after completion of the programme, an aspect considered to be evidence of the generalisability

of an intervention. A follow-up assessment would shed light on how these improved cognitions/skills are maintained over time.

## Chapter IV

# A THREE-MONTH FOLLOW-UP STUDY TO EXPLORE THE EFFECTS OF INTERVENTION ON READING DIFFICULTIES

### 4.1 INTRODUCTION

Reading disorder is known to affect 5–17.5% of school-children (Shaywitz & Shaywitz, 2005). Research in the areas of cognitive development, genetics and neuropsychology has clearly established the causal nature of phonological deficits for many reading difficulties (Frith, 1997; Paulesu et al., 1996; Wise, Ring, & Olson, 2000).

Evidence that phoneme awareness plays a causal role in reading difficulties comes from intervention studies. Phonological awareness skills are directly associated with aspects of reading. Training on phonological processing skills is reported to show improved decoding skills (Ramus, 2003; Gillon & Dodds, 2001; Shaywitz et al., 2003, 2005). (For a full review of this matters, see previous chapters.) Also, although children experiencing phonologically trained conditions make more impressive gains in phonological skills than when they experience reading-trained conditions, the advantage tends to have a less significant impact on standardised tests of word reading. Such results highlight the need to address various related components of reading in addition to phonological awareness such as reading accuracy, speed and comprehension, language based skills and cognitive functions such as attention, memory and organization. Several of these components play a supportive role in the process of reading rather than directly influencing the process of reading.

Follow-up studies are crucial for determining if the gains made after intervention have been sustained over time, and to establish the long-term benefits of a training programme. Such studies allow researchers to identify factors that contribute to improved reading and are maintained long after termination of the training.

Studies tracking the development of reading show that individuals with reading disorder in childhood continue to display signs of reading difficulties into adulthood if they do not receive any intervention for their difficulties (Puranik, Petscher, Otiaba, Catts, & Lonigan, 2008; Ritter, 1978; Wocadlo & Rieger, 2007). Studies that have explored the benefits of an intervention programme over time included those by (Fossett & Miranda, 2006; Tressoldi, Vio, & Iozzino, 2007). Tressoldi and colleagues conducted a meta-analysis of intervention studies in reading disability. Effects of intervention were shown on the trained tasks and some aspects of reading. The authors also studied the effects of training on orthography in reading difficulties. They found that children who received training on orthography showed improved reading fluency along with reading accuracy.

In the study documented in Chapter III of this thesis, 20 children with reading disorder were provided with intervention for their reading difficulties. They were randomly allotted to one of two treatment groups: one group received phonological awareness skills training; the other group received neuropsychological intervention. The effects of training on reading, phonological awareness skills and neuropsychological functions were examined. Results indicated that reading improved significantly for both the groups. Although both groups improved significantly on neuropsychological functions and phonological awareness skills, differences in their response to intervention

were noticed. The study documented in this present chapter explores the benefits of the two training programmes three months after completion of the intervention. Evidence from a search of existing literature suggests that children maintain the improvements in their reading a few months to a year after the intervention. However, how the other associated cognitions develop or change in response to intervention were not explored by the researchers. We accordingly decided there is a need to study how both neuropsychological functions and reading developed after completion of the intervention, and we set the time period at three months after. We hypothesised that:

1. The two training groups would maintain the improvement they made in neuropsychological, reading and phonological measures three months after intervention.
2. The cognitive profiles of the two groups would show differential response to treatment after three months.

To test these hypotheses, the 20 children with reading disability were re-assessed three months after termination of intervention.

## **4.2 METHOD**

The 20 children with reading difficulty selected for the study described in Chapter III were assessed before the onset of the intervention and after completion of the intervention. These two assessments formed part of this previous study. After termination of the post-intervention assessment, the children were encouraged to practise the techniques taught during the training programme, but they received no further input. The children were also encouraged to attend school as usual, and their parents were encouraged to keep in regular contact with the author to verify that the children were not

receiving any special education inputs. The parents were also asked to provide details (marks obtained in school) about their children's progress at school.

Three months after the completion of the intervention, the parents of each child were contacted and permission was sought to assess the children on neuropsychological, phonological and reading tests. Each child was assessed individually. Assessment took about three to four hours for each child and occurred across one or two sessions. Each session was videotaped and later verified by an independent evaluator for consistencies in administration and scoring. As part of the verification process, the evaluator viewed the assessment tapes of one child. After seeking clarification from the author about the nature of some of the assessment tools used, the evaluator verified that the scoring and administration of the tests were conducted according to the instructions set down in the prescribed manuals. The results of the follow-up assessment are presented below, and are compared with the results of the previous two (pre-intervention and post-intervention) assessments.

### **4.3 RESULTS**

The two groups—phonological awareness and neuropsychological intervention—were assessed on neuropsychological, reading and phonological measures before and after intervention (for details of these assessments, see Chapter III). Three months after the conclusion of the intervention programme, the children were again assessed through use of neuropsychological, phonological and reading tests. In the current study, the scores on the neuropsychological and reading tests were compared to those of the previous two assessments. Scores of the post-intervention assessment and the follow-up assessment were compared to explore changes over time. The follow-up scores were also compared



with the pre-intervention scores to help identify significant improvements not noticed at the post-intervention assessment.

Student *t*-test (two-tailed, dependent) was used to assess the significance of difference within the two intervention groups across the three assessments. The comparisons made included changes from pre-intervention to post-intervention, pre-intervention to follow-up assessment and post intervention to follow up assessment. Repeated measures ANOVA was used to assess the significance of change across time for each of the intervention groups. Two by three repeated measures of analysis of variance (RMANOVA) was used to assess the group (PA versus NP group) by time (pre-, post- and follow-up assessments) interaction. The results are discussed for the two intervention groups individually. This is followed by an examination of the interaction of the two interventions across time.

### **4.3.1 Phonological Awareness Group**

#### **4.3.1.1 Neuropsychological measures at follow-up**

Table 4.1 presents the results of the neuropsychological measures across three assessments for the PA group. The scores revealed that on digit span ( $t(9) = 1.413$ ;  $p = 0.051$ ) and interference control (Stroop Colour-Word Test, colour-word trial:  $t(9) = 2.338$ ;  $p = 0.44$ ), the PA group showed a statistically significant increase at post assessment. On spatial span (backward), the trend was towards significance only ( $t(9) = 2.058$  ;  $p = 0.07$ ). The group results did not indicate significant change in the post-intervention score on other neuropsychological variables.

Table 4.1: Comparison of neuropsychological measures across the three assessments, PA group

Neurological test measures	PA-pre		PA-post		PA-follow-up		Significance (p-value)				
	Mean	SD	Mean	SD	Mean	SD	p-value	RMANOVA (2,27)	Pre-post	Pre minus follow-up	Post minus follow-up
Digit forward	8.60	1.9	8.00	2.3	8.70	2.1	0.165	0.165	0.357	0.823	0.191
Digit backward	5.30	1.6	5.70	1.6	4.10	1.4	0.608	0.608	0.423	0.678	0.443
Digit span	10.20	1.5	9.60	2.0	9.20	1.5	0.152	0.152	0.297	1.000	0.051
Spatial forward	8.50	1.9	8.70	1.5	7.60	1.6	0.416	0.416	0.678	0.693	1.000
Spatial backward	6.80	1.9	7.70	1.6	7.20	1.7	0.104	0.104	0.235	0.019	0.070
Spatial span	10.90	1.6	11.50	1.4	10.30	1.8	0.662	0.662	0.168	0.173	0.876
Fluency Trial 1	6.50	2.2	8.40	2.3	11.50	2.9	<0.001**	<0.001**	0.030	0.028	0.434
Fluency Trial 2	5.90	3.7	6.80	3.6	8.90	2.9	0.050*	0.050*	0.287	0.307	0.856
Fluency Trial 3	7.70	3.1	7.60	3.8	12.10	2.9	0.002**	0.002**	0.916	0.372	0.450
Colour Trail A	101.50	33.5	75.60	21.0	79.80	22.21	0.128	0.128	0.039	0.010	0.887
Colour Trail B	167.50	40.1	153.30	44.3	163.3	42.8	0.522	0.522	0.516	0.060	0.716
Stroop W	62.30	17.0	68.50	16.4	66.90	11.7	0.013*	0.013*	0.069	0.047	0.711
Stroop C	49.60	11.5	49.20	20.2	51.10	6.6	0.005**	0.005**	0.941	0.007	0.185
Stroop CW	24.90	7.6	27.40	5.8	24.80	3.2	0.063+	0.063+	0.248	0.011	0.044
Verbal Learning-1	7.00	2.4	8.70	2.3	7.70	1.2	0.037*	0.037*	0.152	0.083	0.864
Verbal Learning-2	9.00	2.6	10.70	2.0	10.30	2.6	0.024*	0.024*	0.009	0.060	1.000
Verbal Learning-3	10.60	2.1	11.20	2.7	11.40	2.3	0.032*	0.032*	0.475	0.077	0.351
Verbal Learning-4	12.20	1.8	12.70	1.8	12.00	2.4	0.212	0.212	0.440	0.132	0.808
Verbal Learning-5	12.20	1.2	13.30	1.2	12.00	2.7	0.602	0.602	<0.001	0.107	0.853
Verbal Learning-total	51.00	7.5	56.20	7.3	53.40	10.0	0.018*	0.018*	0.035	0.015	0.512
Verbal Memory-imm	10.60	2.0	11.70	2.5	11.50	2.8	0.164	0.164	0.343	0.043	0.210
Verbal Memory-delayed	11.70	2.1	12.30	1.8	11.50	2.3	0.093+	0.093+	0.483	0.032	0.299
Complex Figure Copy	34.20	1.2	32.60	4.3	34.70	1.2	0.062+	0.062+	0.235	0.859	0.209
Complex Figure-imm	21.40	9.1	27.50	5.9	28.20	5.1	0.025*	0.025*	0.023	0.016	0.510
Complex Figure-delayed	22.90	6.6	27.65	5.5	27.60	5.2	0.359	0.359	0.029	0.030	0.555

Notes: PA= Phonological Awareness intervention group; Fluency = Controlled Word Association; Digit backward = backward series of digit span; Corsi total = Total score on Corsi Block Tapping Test; CTA = Colour Trail Form A; CTB= Colour Trail Form B; Stroop W = Stroop Colour Word Interference Test, word trial; Stroop C = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; Verbal Learning = AVLT Trials 1–5; Verbal Memory-imm = immediate recall on AVLT; Verbal Memory-delayed = delayed recall on AVLT; Complex Figure Copy = score obtained on copy trial of test; Complex Figure-imm = immediate recall of text; Complex Figure-delayed= score obtained on delayed recall of CFT

\*  $p < .05$ ;  $t$ -test for two population means (method of paired comparisons)

A comparison of the pre-intervention scores with the follow-up scores revealed that some measures (not significant at the post-intervention assessment) were significantly higher at the time of the follow-up assessment. These measures were the Stroop Colour-Word Test, Colour trial ( $t(9) = 3.480$ ;  $p = 0.007$ ), immediate verbal memory (Auditory Verbal Learning Test-immediate:  $t(9) = 2.349$ ;  $p = 0.043$ ) and delayed verbal recall on the same test [ $t(9) = 2.538$ ;  $p = 0.32$ ]. Set-shifting as seen on Colour Trail B ( $t(9) = 2.152$ ;  $p = 0.06$ ) and Verbal Learning Trials 1 ( $t(9) = 1.963$ ;  $p = 0.083$ ) and 3 ( $t(9) = 1.993$ ;  $p = 0.077$ ) showed a trend towards significance.

RMANOVA was conducted to assess the significance of the changes across all three assessments. As evident in Table 4.1, the PA group showed a significant increase across the three assessments in spatial span backward series ( $F(2,27) = 4.311$ ;  $p = 0.03$ ), verbal fluency Trial 1 ( $F(2, 27) = 5.116$ ;  $p = 0.017$ ), Colour Trail A ( $F(2, 27) = 4.484$ ;  $p = 0.02$ ), Stroop word reading ( $F(2, 27) = 3.737$ ;  $p = 0.044$ ), Stroop Colour-Word series ( $F(2, 27) = 6.049$ ;  $p = 0.010$ ), Verbal Learning Trials 2 ( $F(2, 27) = 3.995$ ;  $p = 0.037$ ) and 5 ( $F(2, 27) = 4.581$ ;  $p = 0.021$ ), immediate visual memory (Complex Figure-immediate:  $F(2, 27) = 6.628$ ;  $p = 0.007$ ), and delayed visual memory on Complex Figure ( $F(2, 27) = 4.758$ ;  $p = 0.022$ ).

#### **3.4.1.2 Reading and phonological awareness measures**

Assessing reading skills three months after intervention (see Table 4.2) revealed that the PA group had maintained the gains in reading ( $X = 489.9$ ,  $SD = 70.01$ ). Although the means from post treatment to follow-up assessment did not show a significant increase ( $t(9) = 0.066$ ;  $p = 0.57$ ), the children's scores at the time of the follow-up assessment were significantly higher than at the time of the pre-intervention ( $t(9) = 4.238$ ;  $p = 0.002$ ).

Non-word reading scores showed an increase from post-intervention ( $X = 7.7$ ;  $SD = 6.7$ ) to follow-up assessment ( $X = 8.3$ ,  $SD = 2.75$ ). However, this increase was not statistically significant ( $t(9) = 0.243$ ;  $p = 0.813$ ). A comparison of the non-word reading scores from pre-intervention to follow-up assessment revealed that the non-word reading scores for the children were significantly higher at follow-up ( $t(9) = 2.892$  ;  $p = 0.018$ ). Phoneme segmentation scores (mean scores) increased from 4.7 at pre-intervention to 7.6 at post-intervention assessment. These scores had further increased to 8.2 by the time of the follow-up assessment, but this was not statistically significant ( $t(9) = 1.470$ ;  $p = 0.176$ ).

*Table 4.2: Comparison of reading and phonological measures at follow-up assessment, PA group*

Test	Pre-intervention		Post-intervention		Follow-up		Pre-follow-up		Post-follow-up	
	X	SD	X	SD	X	SD	T score	p	T score	p
Reading	383.0	158.0	488.0	167.0	489.9	70.01	4.283	0.002*	0.66	0.949
NWR	4.2	3.8	7.7	6.70	8.3	2.75	2.892	0.018*	0.243	0.813
PS	4.7	2.0	7.60	3.1	8.20	6.07	1.826	0.101	1.470	0.176

Notes: NWR= non-word reading; PS = phoneme segmentation

\*  $p < .05$ ; t-test for two population means (method of paired comparisons)

### 4.3.2 NP Group at Follow-up Assessment

#### 4.3.2.1 Neuropsychological measures at follow-up

Table 4.3 depicts the mean and standard deviation of the neuropsychological assessment for the NP group: scores for all the neuropsychological assessment measures increased between the post-intervention and follow-up assessments. However, only spatial span (backward) showed a trend towards significance; all other changes were not significant.

The pre-intervention scores were compared to the follow-up assessment scores. This comparison revealed that the follow-up scores were significantly higher than the pre-intervention scores on the following measures: Colour Trail A ( $t(9) = 2.503$ ;  $p = 0.034$ ), verbal learning on Auditory Verbal Learning Test Trials 1 ( $t(9) = 3.354$  ;  $p =$

0.008), 2 ( $t(9) = 2.744$  ;  $p = 0.023$ ), and 3 ( $t(9) = 2.491$ ;  $p = 0.034$ ), and visuo-spatial perception as assessed on the Complex Figure Test-copy trial ( $t(9) = 2.81$  ;  $p = 0.02$ ) At post-intervention assessment, these scores did not differ significantly from pre-intervention scores. Digit forward ( $t(9) = 1.901$ ;  $p = 0.09$ ) and digit span ( $t(9) = 2.021$ ;  $p = 0.075$ ), spatial span backward ( $t(9) = 1.861$ ;  $p = 0.096$ ) and delayed recall on the Auditory Verbal Learning Test ( $t(9) = 1.908$  ;  $p = 0.089$ ) showed significance trends.

#### **4.3.2.2 Phonological measures and reading at follow-up**

Reading scores (see Table 4.4) showed an increase in mean score of 346 ( $SD = 144.44$ ) to 437.6 ( $SD = 126.27$ ) at the post-intervention assessment. By the time of the follow-up assessment, the mean scores had increased to 477.4 ( $SD = 74.29$ ), but the increase was not statistically significant ( $t(9) = 1.67$ ;  $p = 0.13$ ). However, comparison of the pre-intervention reading score with that of the follow-up assessment revealed a significant difference ( $t(9) = 3.193$ ;  $p = 0.011$ ). Non-word reading and phoneme segmentation scores had not increased significantly by the time of the follow-up assessment.

RMANOVA for the NP group at follow-up assessment revealed that verbal fluency Trial 1 ( $F(2, 27) = 20.61$  ;  $p < 0.01$ ), Trial 2 ( $F(2, 27) = 3.53$ ;  $p = 0.083$ ) and Trial 3 ( $F(2, 27) = 9.283$ ;  $p = 0.006$ ) showed significant change across time. In addition, Stroop word reading ( $F(2, 27) = 5.606$ ;  $p = 0.053$ ), Stroop colour reading ( $F(2, 27) = 7.147$ ;  $p = 0.010$ ), Verbal Learning Trials 1 ( $F(2, 27) = 3.971$ ), 2 ( $F(2, 27) = 4.634$ ), and 3 ( $F(2, 27) = 4.209$ ), total learning ( $F(2, 27) = 5.080$ ;  $p = 0.086$ ) and immediate recall on Complex Figure ( $F(2, 27) = 4.536$ ;  $p = 0.030$ ) showed a significant positive effect of time. Colour-word reading on the Stroop Colour-Word Test showed a trend towards significance ( $F(2, 27) = 3.241$ ;  $p = 0.020$ ).

Table 4.3: Comparison of neuropsychological measures across the three assessments, NP group

Neurological test measures	NP-pre		NP-Post		NP-Follow-up		Significance (p-value)				
	X	SD	X	SD	X	SD	p-value	RMANOVA (2, 27)	Pre-post	Pre-follow-up	Post-follow-up
Digit forward	7.40	1.4	8.20	2.1	8.70	2.1	0.165	1.998	0.269	0.090	0.427
Digit backward	3.60	1.4	4.00	1.3	4.10	1.4	0.608	0.512	0.494	0.397	0.823
Digit span	8.10	1.4	9.20	2.2	9.20	1.5	0.152	2.098	0.178	0.075	1.000
Spatial forward	7.00	1.2	7.90	2.8	7.60	1.6	0.416	0.791	0.262	0.140	0.758
Spatial backward	6.20	2.0	6.20	1.5	7.20	1.7	0.104	2.571	1.000	0.096	0.096
Spatial span	9.90	1.9	10.00	1.4	10.30	1.8	0.662	0.422	0.758	0.443	0.576
Fluency Trial 1	6.90	2.6	11.50	2.3	11.50	2.9	<0.001*	20.610**	<0.001	<0.001	1.000
Fluency Trial 2	6.10	1.8	7.70	2.7	8.90	2.9	0.050*	3.534*	0.083	0.042	0.317
Fluency Trial 3	7.30	2.9	12.90	5.2	12.10	2.9	0.002**	9.283**	0.006	0.001	0.634
Colour Trial A (CTA)	99.40	31.0	92.40	29.5	79.80	22.1	0.128	2.314	0.452	0.034	0.271
Colour Trial B (CTB)	178.50	78.7	178.20	67.1	163.30	42.8	0.522	0.675	0.978	0.425	0.350
Stroop W	57.30	12.9	63.10	15.1	66.90	11.7	0.013*	5.606*	0.053	0.011	0.239
Stroop C	43.60	7.4	49.90	7.3	51.10	6.6	0.005**	7.147**	0.010	0.005	0.629
Stroop CW	21.90	4.8	26.20	4.3	24.80	3.2	0.063+	3.241+	0.020	0.181	0.404
Verbal Learning-1	5.70	1.8	6.70	2.9	7.70	1.2	0.037*	3.971*	0.221	0.008	0.221
Verbal Learning-2	7.20	3.3	9.20	3.5	10.30	2.6	0.024*	4.634*	0.123	0.023	0.170
Verbal Learning-3	9.40	1.8	10.90	2.1	11.40	2.3	0.032*	4.209*	0.096	0.034	0.343
Verbal Learning-4	10.60	2.5	11.70	1.3	12.00	2.4	0.212	1.692	0.207	0.182	0.616
Verbal Learning-5	11.20	2.7	11.90	2.6	12.00	2.7	0.602	0.522	0.466	0.462	0.847
Verbal Learning -total	43.90	10.3	50.40	10.9	53.40	10.0	0.018*	5.080*	0.086	0.028	0.135
Verbal Memory-imm	9.00	3.4	10.80	2.7	11.50	2.8	0.164	2.004	0.177	0.113	0.575
Verbal Memory-delayed	9.10	3.8	11.40	2.1	11.50	2.3	0.093+	3.281	0.100	0.089	0.832
Complex Figure-copy	33.05	2.3	34.00	2.3	34.70	1.2	0.062+	3.267	0.227	0.020	0.285
Complex Figure-imm	23.50	6.8	27.10	5.0	28.20	5.1	0.025*	4.536*	0.030	0.025	0.537
Complex Figure-delay	24.85	7.2	26.50	5.5	27.60	5.2	0.359	1.086	0.157	0.286	0.575

Notes: NP = Neuropsychological intervention group; Fluency total = total words generated across three trials of Controlled Word Association; Digit backward = backward series of digit span; Spatial forward = score on forward series of Corsi Block Tapping Test; Spatial backward = score on backward series of Corsi Block Tapping Test; Spatial span = total score on Corsi Block Tapping Test; CTA = Colour Trail Form A; CTB = Colour Trail Form B; Stroop-C = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; Verbal Learning = AVLT; Complex Figure-copy = score obtained on copy trial of Complex Figure Test; Complex Figure-imm = immediate recall of the Complex Figure Test; Complex Figure-delay = score obtained on delayed recall of CFT.

\*  $p < .05$ ;  $t$ -test for two population means (method of paired comparisons)

### 4.3.3 Comparison of the PA and NP Groups

#### 4.3.3.1 Neuropsychological measures

The two groups were compared for their performances on the neuropsychological measures from post-intervention to follow-up assessment. Table 4.5 shows the group performances at follow-up. The PA group mean was significantly higher than the NP group mean on digit backward ( $t(18) = 2.232$ ;  $p = 0.039$ ) and on interference control (Stroop Colour-Word Test, colour-word trial) ( $t(18) = 3.740$ ;  $p = 0.001$ ). The performances of the two groups on the other neuropsychological measures were comparable.

*Table 4.4: Comparison of the reading and phonological measures across the three assessments, NP group*

<i>Test</i>	<i>Pre-intervention</i>		<i>post-intervention</i>		<i>Follow-up</i>		<i>Pre-follow-up</i>		<i>Post-follow-up</i>	
	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>	<i>X</i>	<i>SD</i>	<i>T score</i>	<i>p</i>	<i>T score</i>	<i>p</i>
Reading	346.0	144.440	437.60	126.27	474.4	76.29	3.193	0.011*	1.670	0.139
NWR	3.0	3.1	5.4	4.1	6.00	3.27	1.946	0.084+	0.398	0.683
PS	5.3	1.3	5.0	2.7	6.5	4.51	1.253	0.242	0.964	0.360

*Notes:* NWR= non-word reading; PS = phoneme segmentation

\*  $p < .05$ ; t-test for two population means (method of paired comparisons)

A 2 x 3 RMANOVA was used to estimate the response to the two interventions over time. The factors considered were two (intervention) groups, that is, phonological awareness PA and neuropsychological intervention NP, and three time periods—pre-intervention, post-intervention and follow-up assessments—as well as the group by time interaction.

Table 4.5: Comparison of PA group with NP group at follow-up assessment

Neuropsychological measures	PA group		NP group		t-value	p-value
	X	SD	X	SD		
Digit forward	8.7	1.49	8.7	2.11	0.00	1.00
Digit backward	5.5	1.43	4.1	1.37	2.232	0.039*
Digit span	10.2	1.42	9.2	1.47	1.515	0.145
Spatial forward	8.7	1.94	7.6	1.64	1.364	0.189
Spatial backward	8.5	1.77	7.2	1.68	1.677	0.111
Spatial span	11.6	1.83	10.8	1.76	1.613	0.124
Fluency total	24.7	6.50	30.2	7.31	1.767	0.094+
Colour Trail A (CTA)	74.1	28.74	79.8	22.06	0.497	0.625
Colour Trail B (CTB)	147.5	31.62	163.3	42.83	0.882	0.389
Stroop W	69.4	17.34	66.9	11.73	0.318	0.710
Stroop C	56.0	11.6	51.1	6.57	1.162	0.260
Stroop CW	32.0	5.16	24.8	3.19	3.740	0.001**
Verbal Learning-1	8.6	1.42	7.7	1.15	1.546	0.140
Verbal Learning-2	10.7	1.76	10.3	2.62	0.400	0.694
Verbal Learning-3	12.00	1.82	11.4	2.31	0.643	0.528
Verbal Learning-4	12.9	1.96	12.0	2.40	0.916	0.377
Verbal Learning-5	13.2	1.93	12.0	2.70	1.141	0.269
Verbal Learning-total	57.6	6.89	53.4	9.97	1.095	0.288
Verbal Memory-delayed	12.8	1.81	11.5	8.32	1.396	0.180
Complex Figure-copy	34.3	1.33	34.7	1.15	0.715	0.484
Complex Figure-imm	26.6	5.18	28.2	5.09	0.696	0.495
Complex Figure-D	26.7	5.20	27.6	5.23	0.386	0.704
Block Design	32.8	6.57	29.8	9.49	0.821	0.422

Notes: NP = Neuropsychological intervention group; Fluency total = Total words generated across three trials of Controlled Word Association; Digit backward = backward series of digit span; Spatial forward = score on forward series of Corsi Block Tapping Test; Spatial backward = score on backward series of Corsi Block Tapping Test; Spatial span = total score on Corsi Block Tapping Test; CTA = Colour Trails Form A; CTB = Colour Trails Form B; Stroop-C = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; Verbal Learning = AVLT; Complex Figure-copy = score obtained on copy trial of Complex Figure Test; Complex Figure-imm = immediate recall on the Complex Figure Test; Complex Figure-delay = score obtained on delayed recall of CFT

\*  $p < .05$ ; t-test for two population means (method of paired comparisons)



The F ratios for all three factors are reported in Table 4.6 The neuropsychological variables that significantly increased over time included verbal fluency Trial 2 ( $F(2, 57) = 3.798, p = 0.004$ ), Colour Trail A ( $F(2, 57) = 6.377; p = 0.004$ ), Stroop word reading ( $F(2, 57) = 9.079, p = 0.001$ ), Verbal Learning Trials 2 ( $F(2, 57) = 8.169; p = 0.001$ ) and 3 ( $F(2, 57) = 5.273; p = 0.010$ ), total learning score on verbal learning ( $F(2, 57) = 10.064; p < 0.001$ ), immediate memory on verbal learning ( $F(2, 57) = 4.172; p = 0.023$ ), immediate recall on Complex Figure ( $F(2, 57) = 10.789; p < 0.001$ ) and delayed recall on Complex Figure ( $F(2, 57) = 4.522; p = 0.018$ ).

Time and group interactions were significant for digit backward ( $F(2, 57) = 14.85; p < 0.001$  for time and  $F(2, 57) = 7.602; p = 0.013$  for group) and delayed recall on verbal memory ( $F(2, 57) = 4.739$  for time and  $F(2, 57) = 3.872$  for group).

Time, group and group by time interactions were significant for Verbal Fluency Trial 1 ( $F(2, 57) = 22.962$  for time;  $F(2, 57) = 4.632$  for group and  $F(2, 57) = 2.977$  for group x time), Trial 3 ( $F(2, 57) = 6.489$  for time;  $F(2, 57) = 4.834$  for group; and  $F(2, 57) = 5.126$  for group x time) and Stroop Colour-Word reading ( $F(2, 57) = 7.188$  for time;  $F(2, 57) = 4.439$  for group;  $F(2, 57) = 2.613$  for group x time).

The groups were also compared on reading scores along with non-word reading and phoneme segmentation.

Table 4.6: Comparison of performance across the three assessments, PA and NP groups

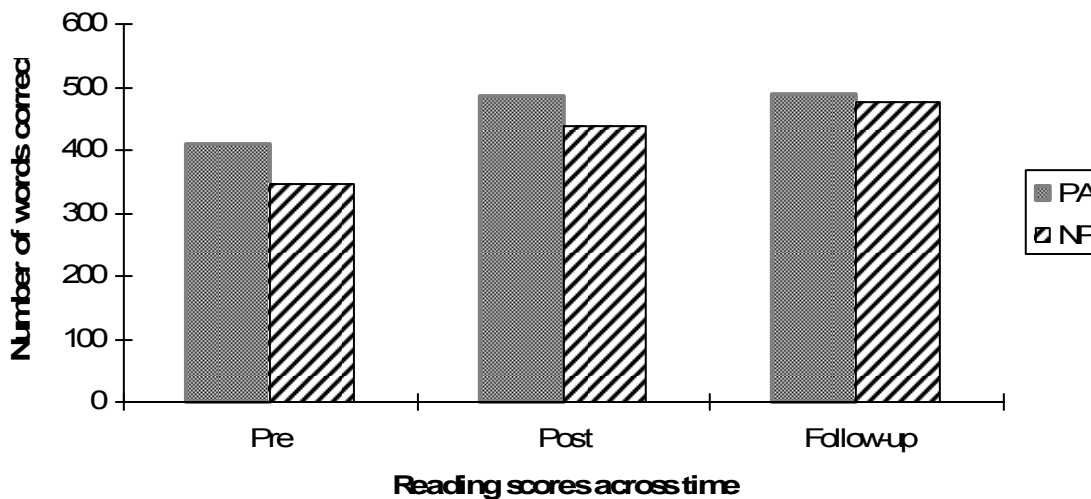
Neurological test measures	Time		Time by Group		Group	
	F-value (2,57)	p-value	F-value	p-value	F value (2, 57)	p-value
Digit forward	1.633	0.209	1.633	0.209	0.225	0.641
Digit backward	14.854	<0.001* *	0.710	0.498	7.602	0.013*
Digit span	1.046	0.392	2.563	0.0811	3.419	0.001**
Spatial forward	0.777	0.426	0.287	0.665	2.863	0.108
Spatial backward	6.355	0.004**	0.751	0.479	3.003	0.100
Spatial span	1.341	0.274	0.274	0.762	3.967	0.062+
Fluency Trial 1	22.962	<0.001* *	2.977	0.064+	4.630	0.045*
Fluency Trial 2	3.798	0.032*	0.710	0.498	0.927	0.349
Fluency Trial 3	6.489	0.004**	5.126	0.011*	4.843	0.041*
Colour Trial A (CTA)	6.377	0.004**	0.989	0.382	0.481	0.497
Colour Trial B (CTB)	1.306	0.284	0.208	0.813	0.703	0.413
Stroop Word	9.079	0.001**	0.302	0.741	0.451	0.510
Stroop Colour	4.331	0.037*	1.149	0.328	0.580	0.456
Stroop Colour & Word	7.188	0.002**	2.613	0.087+	4.439	0.049*
Verbal Learning-1	5.719	0.007**	0.505	0.608	4.060	0.059+
Verbal Learning-2	8.169	0.001**	0.702	0.502	1.676	0.220
Verbal Learning-3	5.273	0.010*	0.376	0.689	0.875	0.362
Verbal Learning-4	2.308	0.114	0.275	0.761	2.982	0.101
Verbal Learning-5	2.311	0.114	0.086	0.918	2.292	0.147
Verbal Learning-total	10.064	<0.001* *	2.836	0.109	0.307	0.738
Verbal Memory-imm	4.172	0.023*	0.120	0.880	2.308	0.146
Verbal Memory-delay	4.739	0.032*	1.069	0.354	3.872	0.065+
Complex Figure -copy	1.959	0.169	2.099	0.137	0.079	0.782
Complex Figure-imm	10.789	<0.001* *	0.550	0.560	0.199	0.611
Complex Figure-delay	4.522	0.018*	0.804	0.455	0.064	0.803

Notes: NP = Neuropsychological intervention group; Fluency total = total words generated across three trials of Controlled Word Association; Digit backward = backward series of digit span; Spatial forward = score on forward series of Corsi Block Tapping Test; Spatial backward = score on backward series of Corsi Block Tapping Test; Spatial span = total score on Corsi Block Tapping Test; CTA = Colour Trail Form A; CTB = Colour Trail Form B; Stroop-C = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; Verbal Learning = AVLT; Complex Figure-copy = score obtained on copy trail of Complex Figure Test; Complex Figure-imm = immediate recall of the Complex Figure Test; Complex Figure-delay = score obtained on delayed recall of CFT

The two groups were comparable on most neuropsychological and phonological abilities at the pre-intervention assessment. With intervention, the two groups improved on several variables, but the rate of improvement varied between the two. This variability was reflected in the reading, digit forward and verbal memory scores. One group was able to show a larger improvement than the other in response to intervention and thus was able to bridge the gap between the groups. However, some of these differences were significant statistically while others were not.

At pre-intervention, the PA group mean was greater than the NP group mean on reading, but this difference was not significant. At post-intervention, it was evident that this difference had been maintained. On the follow-up assessment, the NP group mean was close to the PA group mean as evident in Figure 4.1.

*Figure 4. 1: Reading accuracy across the three assessments for the PA and NP groups*

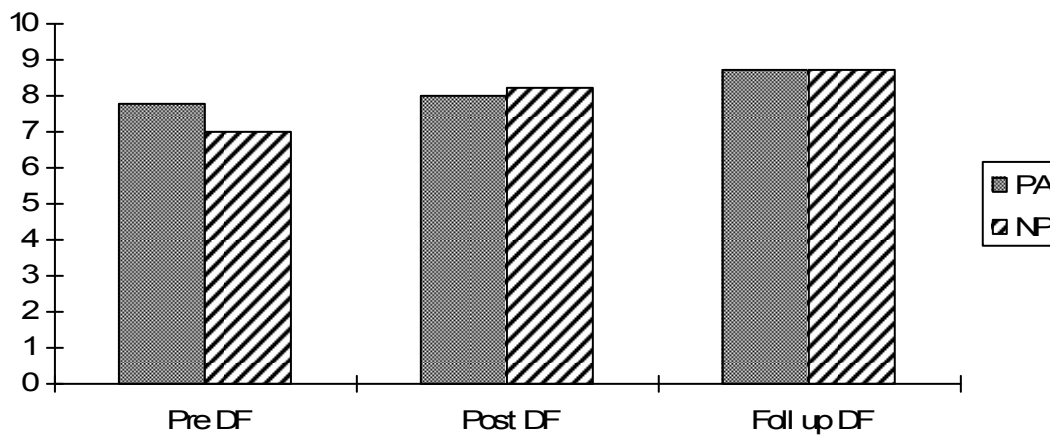


*Notes:* PA = Phonological Awareness intervention group; NP = Neuropsychological intervention group; Pre = pre-intervention assessment; Post = post-intervention assessment; Follow-up = follow-up assessment; Reading scores represent number of words correctly read

The two treatment groups also differed at pre-intervention on digit forward, but this difference was not significant. By the time of the post-intervention assessment, the

two group means were comparable, and by the time of the follow-up assessment, both groups had further increased their scores. Thus, despite a difference at pre-intervention, the two groups were comparable at the post-intervention and follow-up assessments (Figure 4.2).

*Figure 4.2: Digit forward across the three assessments for the PA and NP groups*



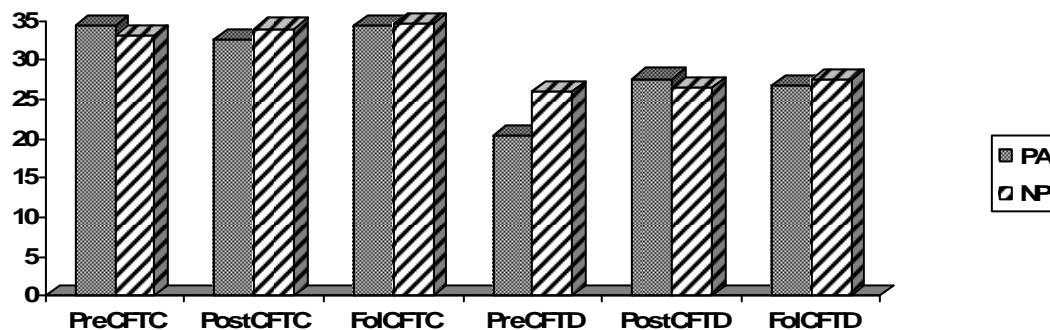
PA = Phonological Awareness intervention group; NP = Neuropsychological intervention group; scores represent number of digits correctly recalled

Pre-DF = digit forward score at pre-intervention assessment; post-DF = digit forward score at post-intervention assessment; follow-up DF = digit forward score at follow-up assessment

The PA group mean was lower than the NP group mean on visual memory (Complex Figure Test, delayed recall) at the pre-intervention assessment. The differences between the two group means at pre-intervention indicated a trend towards significance. At the post-intervention and follow-up assessments, the PA group had moved towards the NP group mean, as evident in Figure 4.3. The mean scores for the two groups were not, however, statistically different at post-intervention. At follow-up assessment, the PA group showed a further increase in scores. The PA group mean was thus comparable to the NP group mean after intervention and this improvement was still evident three

months after intervention. The increase in the visual memory scores showed a significant change over time, as is evident from the time interaction score in Table 4.6.

*Figure 4.3: Verbal memory across the three assessments for the PA and NP groups*



*Notes:* PA= Phonological Awareness intervention group; NP = Neuropsychological intervention group; scores represent number of digits correctly recalled

Pre-CFTC = copy trial on Complex Figure Test at pre-intervention assessment; Post-CFTC = Complex Figure copy score at post-intervention assessment; Follow-up CFTC = Complex Figure copy score at follow-up assessment

Pre-CFTD = delayed recall on Complex Figure Test at pre-intervention assessment; Post-CFTD = Complex Figure delayed recall score at post-intervention assessment; Foll-up CFTD = Complex Figure delayed recall score at score at follow-up assessment

#### 4. 4 DISCUSSION

The follow-up assessment was conducted three months after intervention in order to identify the changes that occurred over time in a group of reading disabled children. These changes were assessed on neuropsychological measures and reading tests. The assessment was compared with two previous assessments in order to identify (i) the changes that occurred from the first assessment conducted before the onset of the intervention, and (ii) the changes, if any, that were apparent three months after the intervention ended. This comparison was achieved by considering the profile at follow-up assessment against the profiles of the pre-intervention and post-intervention assessments.

It was hypothesised that the children would maintain the changes seen at the post-intervention assessment, and that further improvement from the post-intervention assessment would be evident in one of two ways: (i) a significant increase in the post-intervention scores or (ii) a significant increase in the scores evident at the time of the pre-intervention scores but not evident at the time of the post-intervention assessment. The results of the follow-up assessment were compared to the results of both the pre-intervention and post-intervention assessments.

#### **4.4.1 Phonological Group at Follow-up Assessment**

The children in the PA group were trained to manipulate, delete, isolate and segment speech sounds. Existing literature indicates that phonological awareness skills relate directly to the development of reading (Castles & Coltheart, 2004; Gillon, 2000). Any intervention aiming to improve phonological awareness has been shown to increase phonological awareness skills, and this increase, in turn, was hypothesised to transfer to text reading over a period of time (Gillon & Dodds, 2001; Shaywitz et al., 2003, 2005; Ramus, 2003).

The PA group received inputs to enhance their phonological awareness skills. Basing our conjecture on existing literature, we hypothesised that (i) the group would continue to display improved phonological awareness skills at follow-up assessment, and (ii) a generalising effect (i.e., an increase in score) would be seen for reading accuracy.

The findings of the study are in favour of both hypotheses. Improvements in phonological awareness skills were noticed soon after the intervention (see previous chapter for details). The follow-up assessment revealed that reading, non-word reading and phoneme segmentation abilities increased from post-intervention to follow-up

assessment. However, none of these improvements was statistically significant. A comparison of scores on the relevant pre-intervention assessment measures and follow-up assessment measures revealed that non-word reading and real word reading improved significantly. Phoneme segmentation scores increased, but failed to reach statistical significance.

Intervention studies provide evidence that improved phonological processing abilities result in better reading over time (Wise et al., 2000). The current study supports the finding that children who receive training related to their phonological processing abilities improve their reading accuracy. In our previous study (Chapter II), children with reading disorder were comparable to younger typically developing children on reading abilities, suggesting a probable delay in the development process for the reading disorder children. In the current study, children with reading disorder had difficulties in reading accuracy, non-word reading and phoneme segmentation compared with typically developing children of the same age and class. After receiving an intervention programme, the children with reading disorder showed a significant increase in their real word reading and non-word reading (Chapter III).

Three months after the conclusion of the intervention, the gains in both real word reading and non-word reading scores had been maintained. Thus, we concluded that the intervention programme had probably brought about an improvement in reading ability and that the improvement had possibly been maintained over time despite no further inputs being given to the children post intervention.

The neuropsychological functions of working memory, set-shifting, interference control and verbal learning and memory had also all improved by the time of the follow-

up assessment. The executive functions of working memory, set-shifting and interference control were found to be significantly higher at follow-up compared to post-intervention assessment, suggesting a further increase in these cognitions after the conclusion of the intervention programme. Verbal learning and memory functions had become significantly higher across the time spanning than pre-intervention and the follow-up assessments. The differences in these functions between the pre- and the post-intervention assessments were not, however, statistically significant.

The improvements continued to increase three months after the training had stopped. Continued improvements in the absence of inputs indicate that the intervention had initiated a natural—possibly a corrective—process. We therefore propose that the inputs given to the children during the intervention programme could possibly have brought about an automatization of phonological processing abilities, leading to a generalisation effect on reading.

The assessment profile of the PA group is indicative of changes in executive functions (such as working memory, set-shifting and inhibition control, and learning and memory) and in reading and phonological processing skills. Given that our previous study also pointed towards the possible role of executive function deficits in reading difficulties among children with reading disorder, we consider that improvements in executive functions could probably strengthen improvements in reading brought about by other intervention strategies. According to Nobel et al. (2005), three basic cognitive functions are essential in order for a child to be successful academically. These functions include cognitive control (also known as executive functioning), learning, and memory and reading. The PA group showed improvements in all three cognitive functions by the



time of the post-intervention assessment, and they were able to sustain the improvements shown in their reading even three months after conclusion of the intervention.

RMANOVA was used to assess the changes in the neuropsychological profile over time. The PA group results indicated that the functions of attention (Colour Trail A), visuo-spatial working memory (spatial backward), word reading abilities (word reading on the Stroop Colour-Word Test), verbal fluency (Trial 1), verbal learning abilities (total learning on the AVLT) and visual memory (delayed recall on the Complex Figure Test) improved significantly over time. We suggest that the nature of the tasks and the training programme in general used in the intervention might have influenced these changes over time.

Lovett and Steinbach (1997) in their study reported that reading ability is not a unitary function. It involves the intact functioning of several associated cognitions in order for it to occur automatically and in an uninterrupted fashion. The finding that the improvements noticed in reading and phonological processing observed in the PA group stayed in place over time could be due to the improvement in the associated cognitions. This strengthening, in turn, probably occurred as an indirect consequence of the training programme. We therefore suggest that gains made after an effective reading intervention programme will be maintained over time if associated cognitive skills also improve along with the core abilities of word decoding and phonological processing abilities.

#### **4.4.2 Neuropsychological Intervention Group at Follow-up**

Ten children with reading difficulties received neuropsychological intervention. Three months after conclusion of this intervention, assessment revealed this group—the NP group—had made significant gains over the three months since their post-treatment

assessment in reading, non-word reading and visuo-spatial working memory. Significant increases had also occurred across the time period spanning the pre-intervention assessment and the three-month assessment on the following measures: attention and visual scanning (digit forward and Colour Trails A), verbal and visual working memory (digit backward and spatial span), verbal memory (delayed recall on the Verbal Learning Test) and visuo-spatial perception (copy trial of the Complex Figure Test). These increases, however, were not significant at the post-intervention assessment.

In addition to achieving higher scores on the neuropsychological function measures, the NP group had also significantly increased their pre-intervention reading and non-word reading scores by the time of the three-month assessment. No significant findings emerged from our comparison of the post-intervention scores and the follow-up scores. However, the increases in reading and non-word reading scores between pre-intervention and follow-up were statistically significant.

Despite not receiving any phonological inputs, the NP group displayed improved reading and non-word reading scores, suggesting a possible generalisability of the neuropsychological functioning to reading ability. The significant increases from the pre-intervention assessment to the follow-up assessment suggest a possible progressive increase in these functions as a result of the intervention. We hypothesised that the NP group would show improvement not only on the tasks on which they were trained during the intervention, but also on functions that are sub-served by these basic cognitions. The basic cognitions trained in the intervention (i.e., attention, working memory, learning and memory, and fluency) are not known to be directly involved in the process of reading but it is thought they might play a supportive role in the reading process (Price, 2000). We

therefore propose that when deficit cognitions that support the process of reading are targeted in an intervention programme, the training would probably have a generalising effect: not only will the specific cognitions (i.e., those cited above) that were trained improve, but probably also other associated cognitions (reading and word decoding).

The two groups' non-word reading skills and attributes also significantly improved by the time of the follow-up assessment. Thus, the training programmes, although different in their approach, brought about a significant change in the reading abilities and other associated functions of children with reading disorder. However, these responses were not the same for both groups. While the PA group showed improvements across time (i.e., pre-intervention to follow-up assessment) in set-shifting, interference control and visual memory at the follow-up assessment, and also enhanced their reading and phonological awareness skills, the NP group showed improved attention, working memory, verbal fluency, verbal memory, and visual perception. These improvements were either statistically significant or were approaching significance.

These same functions did not show significant improvement increases across the time encompassed by the pre-intervention and post-intervention assessments. We therefore suggest that the difference in response to intervention shown by the two groups can probably be attributed to the differences in the nature of the intervention programmes. Further studies featuring large samples of participants are required to confirm these initial observations.

RMANOVA was used to identify the neuropsychological functions that improved over time as a result of the inputs received by the NP group. The analysis indicated that verbal fluency (all three trials), word reading, colour naming and interference control on

the Stroop Colour-Word Test, initial uptake of information (Trial 1 of the AVTL), total verbal learning ability on the AVTL, and immediate visual memory improved significantly over time.

The NP group received inputs to enhance working memory, verbal fluency and verbal memory. To be successful on the intervention tasks, the participating children needed to ignore irrelevant stimuli (e.g., as evident with the continuous phoneme tracking task) and to hold bits of information online in order to meet task demands (as with the mental manipulation task). (For descriptions of these tasks, see Chapter III). Research shows that when children receive feedback on their performance on training tasks that place increasing demands on them, they probably experience an improvement in executive functions (Schneider, Ennemoser, Roth, & Vise, 1997).

The NP group also exhibited improvements in their reading scores that were maintained across time. Non-word reading scores improved at post-intervention, and the improvement was still evident at the follow-up assessment. We consider the fact that these improvements in reading and non-word reading by the NP group remained across time despite the children receiving no phonological inputs being provided as an indication of a possible reciprocal relation between executive functions and phonological processing ability and their role in reading.

#### **4.3.4 Comparison of the Two Groups at Follow-up Assessment**

The mean scores of the two groups were compared using 2 x 3 RMANOVA. Mean scores were compared for effect of time (pre-, post- and follow-up assessments), group affiliation (PA and NP intervention groups), and interaction between group and time.

Interaction effects were observed for Trials 1 and 3 of the Verbal Fluency Test, and for colour-word reading on the Stroop Colour-Word Test. Trials 1 and 3 on the Verbal fluency (controlled word association) Test is a measure of phonemic fluency. The two groups were comparable on this measure at pre-intervention assessment, but with time and intervention, the NP group scored significantly better than the PA group. This significant improvement for the NP group could possibly be associated with the nature of inputs provided during the intervention. It seems, therefore, that neuropsychological intervention was significantly more effective than the phonological intervention in enhancing verbal fluency.

The PA group, however, improved significantly on inhibition control. Inhibition control is an important aspect of executive functioning. According to Nobel et al. (2005), executive functioning, along with reading and verbal memory, is essential for academic success. The PA group and the NP group were comparable on this measure on both the pre- and post-intervention assessments. However after a gap of three months, assessment revealed that the PA group had improved significantly whereas the NP group had not. We propose that the possible nature of the inputs provided during the PA training could be responsible for this improvement. A closer look at the findings for this measure showed that the children in the PA group improved in two out of the three components (namely reading and executive control) highlighted by Nobel et al. (2005) as essential for academic success.

The neuropsychological functions of visuo-spatial working memory (as measured on the spatial backward series), verbal fluency, visual scanning (as measured on Colour Trail A), Stroop word and colour reading, and verbal learning and visual memory

revealed a significant time interaction. The cognitive skills grouped as executive functions and memory (both verbal and visual) responded well to the interventions over time, with both the PA and NP group showing improvements on these variables, indicating that the interventions could have possibly contributed equally to enhancing these functions.

Variables such as delayed verbal memory and interference control (Stroop Colour-Word reading) indicated a significant time and group interaction, suggesting that the increase in the scores was probably brought about by the nature of the inputs given, with these inputs having an enhancing effect over time. Digit span was the only variable not to show a significant group interaction. The PA group means were significantly higher than the NP group means at pre-intervention assessment for digit span. With the benefit of intervention and time, the PA group showed improvement on digit forward scores. The NP group scores improved from pre-intervention to post-intervention, but their mean scores remained below the PA group mean scores on all three assessments.

Thus, both groups showed improvements in executive functions, verbal and visual learning and memory. The neuropsychological intervention significantly improved verbal fluency, while the phonological awareness intervention significantly improved inhibition control. Both groups were comparable in terms of the improvements that emerged relative to the other neuropsychological variables. Although the PA and NP group differed on digit forward, digit span, visual memory and reading scores at pre-intervention, the differences were not significant. However, intervention inputs and time saw the group means becoming closer to one another. At post-intervention, the two groups were comparable on reading and verbal memory scores.

Findings thus point towards a possibility that both interventions could have been equally effective in bringing about a change in reading accuracy, non-word reading and in neuropsychological functioning. However, because the two interventions were associated with specific changes on selective cognitive abilities, we propose that the two interventions probably worked on different sets of cognitive abilities.

#### **4.5 LIMITATIONS**

The study presented in this chapter is effective in terms of highlighting the progress the two treatment groups made three months after intervention. The assessment provided us with opportunity to explore the changes that were initiated by the intervention programme and then carried forward without any further inputs. The differences in the intervention programmes were maintained despite the variation in improvements noticed across the two treatment groups. However, the study does have several limitations:

1. The two groups were not evaluated on all the phonological awareness tests at the time of the follow-up assessments, an occurrence that limits our ability to identify how phonological processing skills respond to intervention over time.
2. The reading tool used did not have parallel versions and so all 20 children read the same passages for the third time round. Providing parallel passages would have thrown light on the word-attack and word-decoding abilities of the children. Neuropsychological and phonological measures were also repeated across the three assessments. The children's reading scores and neurocognitive performance could therefore have been highly influenced by practice effects. However, as the improvements noticed were not uniform for all the children and across all the tests,

we are confident that the practice effects played only a minimal role in the children's performances.

3. Due to several constraints, the typically developing children could not be assessed after three months. They completed one assessment only. Assessing these children three months on would have helped us identify if developmental changes in children of this age group might have influenced the increase in scores. However, the literature points to growth spurts that lie outside of the age range chosen for the study and a yearly growth spurt only in children of this age range (Hudspeth & Pribram, 1990). We therefore propose that the changes seen in the two treatment groups are indeed a function of the nature of inputs the children received during the intervention rather than a function of normal development.

#### **4.5 CONCLUSIONS**

The study established that when reading intervention targets specific cognitions, improvements are not restricted to the period for which inputs are provided. Both intervention programmes offered to children with reading disorder in this study brought about improvements in reading, although some aspects of neuropsychological functioning were differentially influenced by the two interventions. Nonetheless, we can conclude that both the neuropsychological and phonological awareness interventions successfully improved reading accuracy in children with reading difficulties.



## CHAPTER V

# EFFECTIVENESS OF NEUROPSYCHOLOGICAL INTERVENTION FOR READING DISORDER: A CASE STUDY

### 5.1 INTRODUCTION

Rapid growth spurts are observed in children from birth to the ages of 16 to 17. Within this time span, four crucial ages are noticed where growth is known to be particularly rapid. These spurts take place between one and three years of age, seven and nine years of age, and between 13 and 16 years of age (Hudspeth & Pribram, 1990). These growth spurts include physical, social, emotional and cognitive growth.

During these periods of rapid development, children acquire new skills as they receive inputs from schools in the form of instructions and then practice. These experiences allow children's cognitive abilities to mature, as the children have to make sense of the inputs they receive. In children with developmental delays, instructions received in school bring about changes, but the rate of change noticed and the nature of learning may differ.

According to Bradley and Bryant (1980), the skills of children with reading disorder are comparable to those of younger children who are skilled readers. As such, these children's response to school instruction might differ from that of their peers in the same classroom. Studies employing brain imaging technology report that disabled readers activate different areas of the brain while reading compared to non-disabled readers (Shaywitz & Shaywitz, 2005). After receiving intervention designed to improve reading

and spelling, this difference diminishes, with the functioning of the brain of the disabled readers approaching that of the non-disabled readers (Shaywitz & Shaywitz, 2005). However, response to interventions is not always uniform. Individuals differ in their response to any kind of intervention. Understanding these individual differences would help identifying those factors that augment the recovery process and those that interfere with it.

Intervention studies typically explore changes in a group of individuals in response to the intervention provided. The data are grouped and averaged, and interpretations are then drawn from the results of statistical analysis of that data. However, individual differences in response to intervention are well documented. Each individual responds at his or her own pace to the intervention offered. Socio-cultural differences, differences within the family, emotional and behavioural differences and childhood experiences can alter the deficit pattern (Muris, Mayer, Lint & Hofman, 2008), as can one's response to the intervention. Thus, it is interesting as well as useful to explore individual differences by presenting individual case studies.

The current study provided two different kinds of intervention. The first was a phonological awareness intervention given to 10 children with reading disorder. The second was a neuropsychological intervention, given to another group of 10 children with reading disorder. The previous chapters of this thesis explored the benefits of these two reading interventions and the responses of the two groups individually and together to them. Neuropsychological tests and phonological processing measures were used to identify the changes from before intervention to after intervention. Follow-up assessments further confirmed the findings of the post-intervention assessment findings.

The scores presented in Chapters II, III and the follow-up assessment (Chapter IV) revealed variations in the pre-intervention profiles of the participating children and that the response to intervention differed from one child to another. Parental reports also indicated that each child responded differently to the intervention. By presenting a single case from the 20 children with specific reading disorder, we endeavoured to highlight an individual response to treatment and to identify those factors that could have possibly contributed to improvement of reading skills.

## **5.2 CASE HISTORY**

HK, an 11-year-old boy studying in Class 6 was referred by his school teachers for assessment. His father reported during an interview that he and his wife adopted HK when he was a few months old. He described his wife as sick and lonely at the time, and said that he thought that adopting a child would help his ailing wife recover, especially as not having a child might be one of the reasons for her illness. However, when HK was 18 months old, the mother died and the father remarried. HK's father was unable to provide information about HK's child's biological parents or why he was given up for adoption.

At the time of the assessment, HK was living with his adopted parents. HK was brought to Prasanna Counselling Centre for assessment and possible intervention. Prasanna Counselling Centre is run by a group of volunteers who offer free assessment and intervention to adults and children with psychological problems of all kinds.

The Child Guidance Unit (CGC) of Prasanna functions once a week, offering assessments and intervention to children below the age of 15. Parents are interviewed in order to arrive at a possible working diagnosis, and then the children are given

psychological tests depending on the nature of the presenting complaints. Parents receive feedback about the test findings, along with suggestions for intervention strategies.

Because HK fitted the inclusion criteria for the research study (described in Chapter III), he was referred for screening and possible inclusion in the study. HK was given the Raven's Progressive Matrix (RPM) test to assess for intellectual functioning. During the same session, he was given the reading subtest from the NIMHANS SLD battery. Table 5.1 presents the findings of these two tests.

HK was found to be reading at Class 4 level (both accuracy and comprehension were intact at this level). Because HK was in Class 6 at the time of assessment, the reading assessment revealed that he was two years below his expected level of reading. His score on the RPM placed him in the average range of intellectual functioning.

*Table 5.1: Reading and screening details for HK*

<i>Age</i>	<i>Class</i>	<i>RPM score</i>	<i>Reading level</i>
11.67	6th standard	30 (75th percentile)	4th standard

*Notes:* Age expressed in years; RPM = Raven's Progressive Matrices

HK fit the inclusion criteria for the study. His parents were interviewed to rule out emotional and/or behaviour problems specified in the exclusion criteria. The parental interview used was the Developmental Psychopathology Checklist or DPCL (Shenoy & Kapur, 1985). (For a detailed description of this checklist, refer to the method section of Chapter III.) During the interview, the parents reported both behavioural problems and academic difficulties. The academic difficulties identified were poor and sloppy handwriting, inability to complete notes on time, difficulty in remembering answers learned at home, poor spelling abilities and poor comprehension of text matter. The

parents also reported that HK could read quickly and with some ease if the words were familiar to him. However, he could understand little of what he read. He avoided reading passages with difficult words and said that he could not understand the text. His parents would then have to explain the text a few times before he could understand. HK also failed to remember much of what he learned at home. As a result of all these problems, HK's academic record showed a consistent drop in performance, a drop that had been particularly steep over the previous three years.

HK's parents reported that they were also concerned about the behavioural problems HK displayed. He showed poor motivation to study and avoided extra study time. His playtime often extended beyond the permissible limit, and he would end up having little time to finish homework. His schoolwork remained incomplete, as his writing was slow and illegible. His books got misplaced, and he was reported to be careless with his books. He was comfortable playing with children younger than he, and his behaviour was generally noticed to be age inappropriate. He did not learn from his mistakes and continued to display behavioural difficulties despite being punished for them.

The parents furthermore reported that HK was easily distracted but that his inattention was restricted only to his study time. If he was engaged in an activity that interested him, he could sustain his attention until he had completed the task. He was also known to be a very kind and sensitive child, and would please his grandfather by showing affection and following religious traditions when required.

The outcomes of the DPCL thus pointed to HK having reading, spelling and writing difficulties. Although HK had several behavioural problems (as reported by the parents)

these behaviours were situation-specific, that is, restricted to HK's study and school activities. The diagnosis reached was that of specific learning difficulty with behaviour problems.

The nature of HK's problems was explained to his parents, and they were asked if they would be willing for HK to participate in the research study, given that it was offering intervention for children with the types of difficulties being experienced by HK. The parents were also informed that HK would be placed in any one of the two intervention groups, and that the researcher would have no control over the allocation of HK to the intervention. After 20 sessions, HK would be assessed on all the pre-intervention parameters and then no intervention would be provided for three months. After three months, he would be assessed on the same parameters once again. After this follow-up assessment, if the parents felt HK required further assistance, this would be offered until such time as they considered their child to be an independent learner. The parents gave their consent to bring HK into the centre for further assessment and to participate in 20 sessions of intervention planned, with two sessions per week over a 10-week period.

The researcher then sent a form to HK's teacher, giving the details of the assessment findings in brief and explaining the intervention programme. The teacher was asked to use the CBQ (Rutter's rating scale; see Chapter III for details) to rule out emotional/conduct problems. On the CBQ, Performa B, HK obtained a score of six. The cut-off score on this scale is nine. The conclusion was that HK did not have any behavioural or emotional problems that would interfere with his participation in the intervention. Although both the DPCL and the CBQ indicated the presence of inattention

and impulsivity, these behaviours occurred only during study situations and were more evident at home than at school. A diagnosis of attention-deficit/hyperactivity disorder or of emotional/conduct disorder known commonly to co-occur in children with reading difficulties was thus not warranted for HK.

### **5.3 PLAN**

After the initial screening, HK was identified as having average intellectual abilities and had specific reading disorder (as his current reading level was two years below expected levels). With the consent of his parents, HK was recruited for the study and randomly assigned to the neuropsychological intervention group. His parents received a description of what the intervention programme would involve. They were told that the study would span the following time frame.

- *Stage I:* Assessment on neuropsychological and phonological awareness tests before intervention (August 2006).
- *Stage II:* Intervention programme over a period of 20 sessions, two sessions a week for about 10 weeks. Because of several holidays and school-related activities such as examinations and tests, the intervention extended from August 2006 to December 2006 (3.67 months).
- *Stage III:* Post-intervention assessment on the same tests conducted before the intervention (December 2006).
- *Stage IV:* Follow-up assessment three months after the post-intervention assessment. Because of school holidays and examinations, this assessment was carried out five months after intervention in May 2007. Between December 2006 and May 2007, HK received no further programme-related inputs. He also received

no special inputs at school, except for regular school instructions and parental coaching to help him meet the demands of his schoolwork.

#### **5.4 PRE-INTERVENTION ASSESSMENT**

As previously noted, HK was placed in the neuropsychological intervention group (NP) through random allocation. The NP group consisted of nine other children with similar difficulties. HK was then assessed on the neuropsychological tests and the phonological awareness tests described in Chapter III. Pre-intervention assessment was carried out across three sessions, each of which lasted 90 minutes.

During the initial sessions of assessment, HK was restless. He did not wait until instructions were completed, but began the task immediately. When this behaviour was pointed out to him, he proved generally able to control his impulses, exhibiting only mild impulsivity during subsequent sessions. Table 5.2 shows HK's reading scores in terms of the number of words accurately read before intervention and the same score (reported as a mean score) for the other nine children in the neuropsychological intervention group and the non-impaired readers (normal control group).

It is evident from Table 5.2 that HK was comparable in age and intellectual functioning to the other children in the neuropsychological intervention group. Before the intervention, the number of words that he read accurately (443 words) was higher than the average accuracy of the NP group (335.2 words). However, the number of words accurately read by the normal control group (511.65) was higher than the number HK read (Figure 5.1).



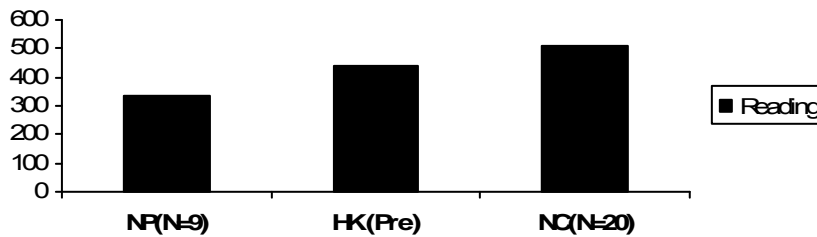
Table 5.2: HK compared with members of NP and NC groups, demographic details

	HK (pre-intervention)	NP (N =9)	NC (N = 20)
Reading	443	335.2	511.65
RPM	30	31.56	NA
Age	11.67	11.30	11.57

Notes: NP = Neuropsychological intervention group without HK; NC = Normal control group; reading scores represented as the number of words read accurately; age for NP and the NC represented as average age (in years) of the group.

On the spelling probe list, HK spelled **drank** as *draink*, **hobby** as *hobi* and **knowledge** as *knoladge*. In the reading passages, he read **penalty** as *penty*, **precious** as *pernicious* and **Shylock** as *snolock*. He displayed poor word-attack skills and read at great speed without regard for punctuation. He displayed difficulty reading and spelling non-words and real words.

Figure 5.1: HK's reading score before intervention



Notes: NP = Neuropsychological intervention group without HK; NC = Normal control group

**Table 5.3: Comparison between HK and children in the NP and NC groups on neuropsychological measures before intervention**

<i>Sl. No</i>	<i>HK (pre)</i>	<i>NP (pre)</i>	<i>NC</i>	
1	Fluency	25	19.8	22.5
2	Digit forward	9	5.7	8.45
3	Digit backward	5	3.2	5.25
4	Digit span	10	7.7	9.6
5	Spatial forward	7	7	7.8
6	Spatial backward	7	6.1	6.6
7	Spatial span total	10	9.9	10.4
8	Stroop W	72	55.7	78.4
9	Stroop C	50	38.8	51.9
10	Stroop CW	23	21.8	28.3
11	Block Design	6	22.1	24.6
12	Colour Trail A	124	96.7	76.85
13	Colour Trail B	173	179.1	135.15
14	Verbal Learning-1	5	5.5	6.95
15	Verbal Learning-2	10	6.8	9.3
16	Verbal Learning-3	9	8.9	10.45
17	Verbal Learning-4	11	10.3	11.8
18	Verbal Learning-5	13	10.6	11.6
19	Verbal Learning-total	48	42.9	50
20	Verbal Memory-delay	7	8.6	10.8
21	Complex Figure-copy	31.5	32.6	34.6
22	Complex Figure-imm	16	24.8	24.25
23	Complex Figure-delay	12	26.3	24.85

*Notes:* Fluency = total words generated across three trials of Controlled Word Association; Digit backward = backward series of digit span; Spatial forward = score on forward series of Corsi Block Tapping Test; Spatial backward = score on backward series of Corsi Block Tapping Test; Spatial span = total score on Corsi Block Tapping Test; CTA = Colour Trail Form A; CTB = Colour Trail Form B; Stroop-C = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; Verbal Learning = AVLT; Complex Figure-copy = score obtained on copy trial of Complex Figure Test; Complex Figure-imm = immediate recall of the Complex Figure Test; Complex Figure-delay = score obtained on delayed recall of CFT; Neuropsychological intervention group without HK ( $N = 9$ ); NC = Normal control group ( $N = 20$ )

### **5.4.1 Neuropsychological Profile before Intervention**

HK's raw scores on the neuropsychological battery before intervention are presented in Table 5.3, as are the average scores on the same tests by the other nine children in the neuropsychological intervention group and the average scores of the 20 control children.

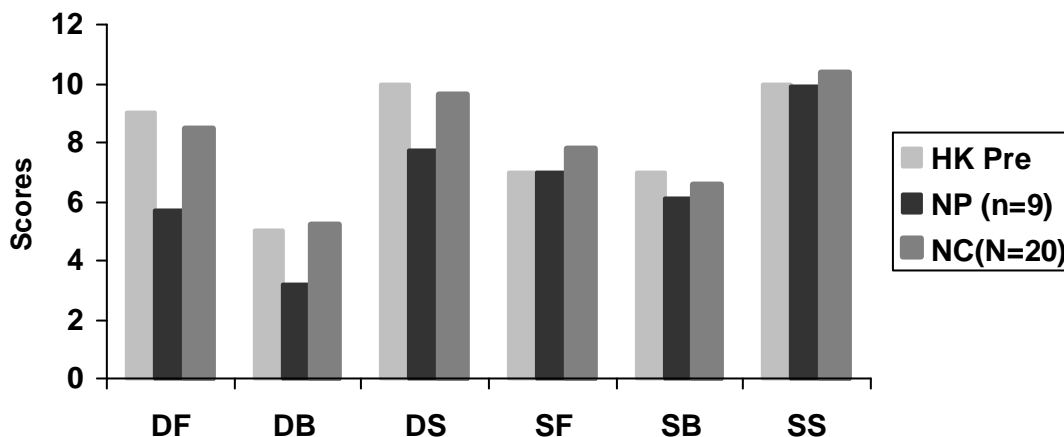
#### **5.4.1.1 Executive functions**

Executive functions include working memory, set-shifting ability, interference control, fluency and planning and organisation. Comparison of HK's performance before intervention with the performance of the neuropsychological intervention (NP) group and the non-disabled readers (NC) group on the tests of executive functions (for details on the test description and details, see Chapter III) indicates that HK did not have many executive function deficits prior to the intervention except for visual scanning and set-shifting ability. On visual scanning (Colour Trail A), HK took longer than the NP and NC children to complete this task pre-intervention, indicating difficulties in this area (Figure 5.3). Interference control and inhibition (Stroop Colour-Word Test) was found to be low in HK compared to the NC group (Figure 5.4). One error on each trial of the Colour Trail Test provided more evidence of poor interference control. Poor planning ability was evident on the Block Design test before intervention. HK had a score of six on the test, a score that was significantly below the NP and NC group means. His behaviour during this subtest was suggestive of frustration especially when he was not able to succeed on an item, and he often gave up before the specified time limit and had to be encouraged to continue for a little longer.

### 5.4.1.2 Verbal learning and memory

Pre-intervention (Trial 1), HK scored below the respective group means on these measures, suggesting that his initial intake of information was much lower than that of the other children his age. His delayed recall score (AVLTD) was also below the mean scores of both groups. His scores on Trials 2 and 5 were above the two group means, indicating that despite initially being slow to learn verbal material, HK was, over time, able to catch up with the NC group. However he was not able to retain this material over time.

*Figure 5.2: Comparison between HK's and other participating children's verbal and visuo-spatial working memory before intervention*



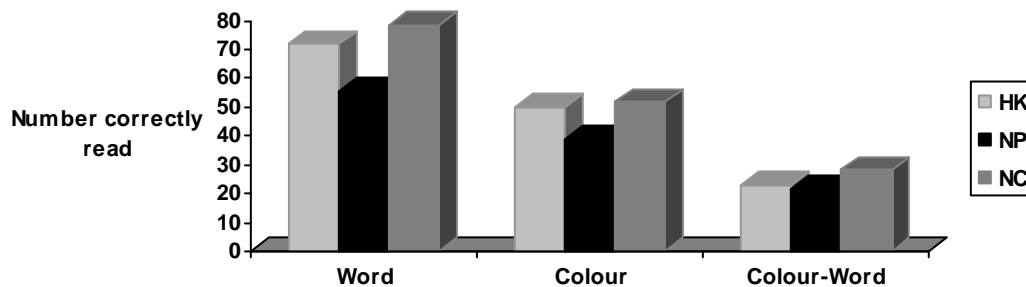
*Notes:* DF = score on digit span forward; DB = score on digit span backward; DS = digit span; SF = score on spatial span forward; SB = score on spatial span backward; ST = spatial span across both trials  
NP = Neuropsychological intervention group without HK; NC = Normal control

### 5.4.1.3 Visual learning and memory

HK's visuo-spatial skills were assessed across three trials. The copy trial on the Complex Figure Test (CFTC) assessed his visuo-spatial perceptual abilities, while his immediate visual memory and delayed visual memory were assessed on the Complex Figure Test-

immediate recall and the Complex Figure Test-delayed recall. HK's ability to copy the figure was similar to that of the children in the NP and the NC groups, indicating adequate visual perception abilities. However, he was significantly lower than both the group averages with regard to the memory trials, indicating that both his immediate memory and delayed visual memory were impaired prior to the intervention.

*Figure 5.3: HK's inhibition control before intervention*



Notes: Word = word reading on Stroop Colour-Word Reading Test; Colour = colour naming on Stroop Colour Word-Reading Test; Colour-word = colour-word reading on Stroop Colour-Word Reading Test  
 NP = Neuropsychological intervention group without HK ( $N = 9$ ); NC = Normal control group ( $N = 20$ )

#### 5.4.1.4 Summary

HK's neuropsychological profile before intervention pointed to the presence of deficits in visual scanning, set-shifting, interference control, inhibition, verbal memory and visual memory. On most other parameters, HK's scores were closer to the non-disabled group means and higher than those of the other children in his intervention group.

#### 5.4.2 Phonological Awareness (PA) before Intervention

HK was assessed on the QUIL, Sthal and Murray and tracking probes before and after intervention. The purpose of this assessment was to identify his PA abilities (baseline performance) before the intervention. Post-intervention assessment sought to determine if

the intervention had brought about changes relative to his baseline performance. The non-disabled reader group was assessed on the QUIL. Table 5.3, Figure 5.5 and Figure 5.6 set out the results of HK's performance on the QUIL against the group average scores for the PP and NC groups on this measure.

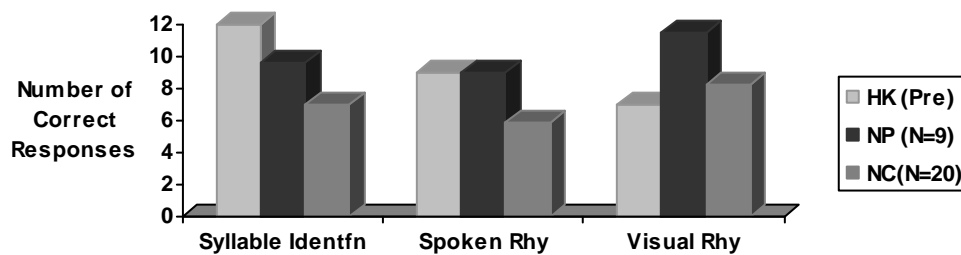
HK showed adequate PA skills on most of the subtests in the QUIL, and his score proved to be closer to the NC group mean than to the NP group mean, suggesting adequate PA skills at the phoneme level and the syllable level. However, on the non-word reading and spoonerism subtests, HK scored significantly lower than both groups, indicating difficulties in these two areas.

*Table 5.4: Phonological awareness for HK before intervention*

	<i>HK (pre)</i>	<i>NP</i>	<i>NC</i>
NWR	1	3.2	11.85
SI	12	9.6	8.1
SS	9	9	11.5
SR	7	5.9	8.2
VR	4	3.9	6.05
Spoon	0	1.6	10.6
PD	10	5.7	8.35
PS	6	5.2	4.55
PDI	6	2.3	6.6

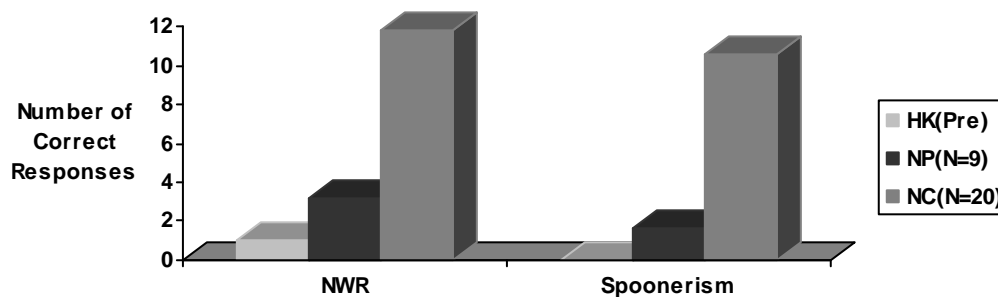
*Notes:* NWR= Non-word reading; SI = syllable identification; SS = syllable segmentation; SR = spoken rhyme; VR = visual rhyme; Spoon = spoonerism; PD = phoneme detection; PS = phoneme segmentation; PDI = phoneme deletion  
 NP = Neuropsychological intervention group without HK; NC = Normal control group

Figure 5.6: Phonological awareness at syllable level before intervention



Notes: Syllable Identfn = syllable identification; Spoken Rhy = spoken rhyme; Visual rhy = visual rhyme  
NP = Neuropsychological intervention group without HK, NC = Normal control group

Figure 5.7: Non-word reading and spoonerism before intervention



Notes: NWR = non-word reading; NP = Neuropsychological intervention group without HK; NC = Normal control group

The overall findings for HK at the pre-assessment indicated the presence of selective deficits in both his neuropsychological and phonological abilities.

## 5.5 NEUROPSYCHOLOGICAL INTERVENTION PROGRAMME

HK received his neuropsychological intervention two days a week for 10 weeks (20 sessions). Because of school holidays, tests and examinations, the intervention period extended from August 2006 to December 2006 for a period of 3.6 months. The intervention method and task are described in detail in Chapter III (main study).

HK was initially given letter cancellation, shading, and grain sorting were used initially as attention tasks as HK because of his being easily distracted. On the letter cancellation task, HK was asked to cancel two letters wherever it appeared in the text provided. He was given 10 minutes to work on this activity. HK made several omissions, and could not complete the task within the given time. His shading was clumsy and dark with excess pressure, and he was unable to follow the instructions given while shading (i.e., to reduce pressure, to make the shading even and light, and to restrict shading to within the given boundaries). As the intervention progressed, he was able to reduce pressure and shade within the drawn boundary. The number of errors he made in his letter cancellation task reduced, suggesting that he had probably gained adequate attentional control on the tasks after 20 sessions.

Tasks such as verbal fluency, temporal ordering and frequency ordering and were proposed to enhance HK's executive functions, such as mental search organisation and planning and encoding of information. HK at first found verbal fluency a challenge, as he was not able to generate more than five to seven words in the two minutes allotted for each letter. He was given strategies on how to search for words beginning with a particular letter. For example, he was asked to think of the possible sound the letter would make and to use that as a cue to search for words. He was also asked to add other letter sounds (phonemes) to the target letter to see how many words he could identify. He was able to act on these instructions: his verbal fluency showed improvement, and toward the end of the intervention, he was able generate more than 20 words per letter in a span of two minutes.



HK found temporal ordering the most difficult of all tasks, as he could not make sentences with the disconnected words. During this activity, he was presented with a list of words divided into three segments. The number of words in each segment varied depending upon the child's performance. For HK, the initial list consisted of six words broken into three segments of two words each. HK was presented with the first two words and asked to make one sentence using both words in the same sentence. He then had to visualise the sentence and hold onto the two words given. This procedure was repeated for the other two segments. Finally, he had to recall all six words in the list. In one session, three such lists were given. Once HK could recall at least five to six words on each list, the length of the list was increased to nine (with three words per segment), 12 words (four words per segment) and 15 words (five words per segment).

The jump from a list of six words to nine words was quick for HK. However, the jump from 9 to 12 words took him a long time, as he was unable to make sentences with different words. The themes/ideas he expressed in his sentences remained very similar. For example, for the words **needle, pen and table**, he made this sentence: "*The pen and needle were on the table.*" For the next set of words (**rope, paper and cycle**), he said, "*The paper and rope were on the cycle.*" He was given feedback on this repetition and asked to consider actively using the objects in his sentences, as that would enhance his ability to remember them.

As his recall across the three lists got better at using concrete and related words, he began to encounter the abstract or unrelated words in the lists, thus increasing the difficulty level for him. In addition, on the third list, HK was asked to make the sentence in his mind rather than speak it out. This meant that the extra auditory feedback he would

get by repeating the sentence and the words was withdrawn. HK had to hold all the words without repeating them to the examiner several times as in the other two trials. (This trial was named the neutral trial.) Thus, he was tested for recall of material that he organised in his mind without external cues. Forgetting was noticed initially on these trials, despite HK having 100% accurate recall on the other two lists of similar length and difficulty level. As the training progressed, he was able to remember all words, even if all three trials were neutral lists. By the end of the 20 sessions, however, he reported being comfortable generating sentences using four words in a group.

Continuous phoneme tapping and mental maths were used as working memory tasks. The former was hypothesised to be a passive working memory task which required HK to report whether the word presented contained a particular phoneme or not. HK had to tap the table to indicate the presence of the phoneme in the words. If he did not tap when the word had the target phoneme or if he tapped for a word that did not have the phoneme, it was counted as an error. Errors were 10 per trial initially and later reduced to three.

When working on the mental mathematics task, HK initially found it very difficult to remember the previous number and he required assistance for this. He took longer to complete the task and also had increased errors. By the end of the 20 sessions, he was able to hold onto the previous number, both rapidly and accurately. The target numbers were then made more difficult by including larger numbers (six to nine) and dropping smaller numbers such as one and two for adding. Thus, accuracy, speed and difficulty levels were changed to enhance active mental manipulations. HK made gains on all the

treatment tasks and reached saturation levels so that the next difficulty level could be introduced.

In his report, HK said that he enjoyed all the tasks. He found the mental mathematics task very challenging, but said he wanted to get to the more difficult levels quickly. On the fluency task, he at first asked for specific letters so that he could easily get to a target of 20 words in two minutes. In later sessions, he asked for letters that he felt he needed more practice with. He showed keen interest in getting feedback on his performances and noted the difference from the present to the previous performance. In this way, he constantly challenged himself and showed good motivation to reach goals that were set on the basis of his previous performance.

After HK had completed his 20 sessions, conducted across 3.6 months, he was assessed in the week following the intervention programme on neuropsychological and phonological awareness tests. Five months later, he was assessed on the neuropsychological tests and non-word reading, reading passages and phoneme segmentation. The results of these two assessments are presented along with the pre-treatment assessment.

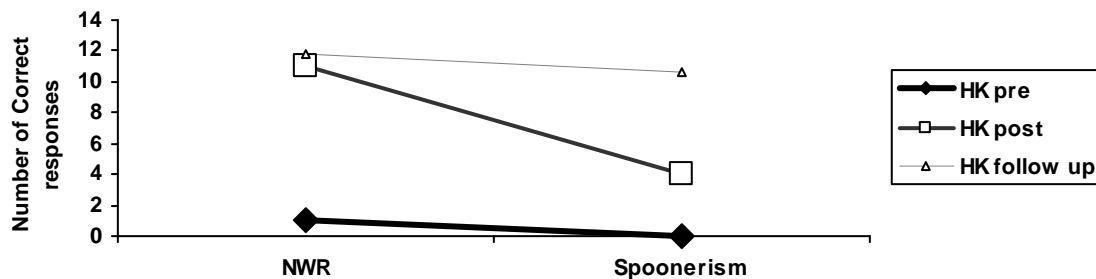
## **5.6 RESULTS**

After completing 20 sessions of intervention, HK was assessed on the same reading, neuropsychological and phonological awareness tests to examine the effects of training on these parameters. Neuropsychological and reading assessment was once again repeated three months after intervention. The remaining figures and table in this chapter

summarise HK's performance across the three assessments to show changes in his reading abilities across time.

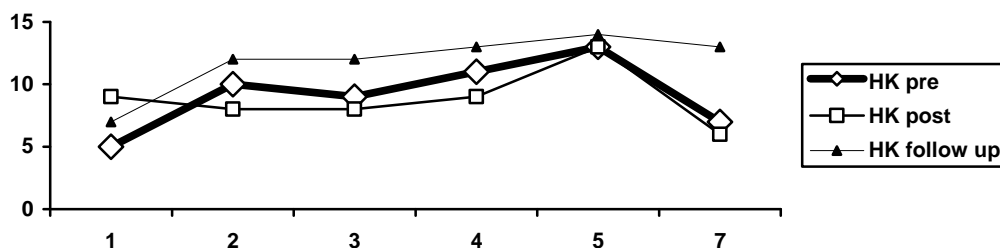
Figures 5.8 to 5.12 compare HK's performance across the three assessments. Post- assessment and follow-up assessments show the change after intervention; pre-assessment shows his baseline performance.

Figure 5.8: HK's performance on non-word reading and spoonerism across three assessments for HK



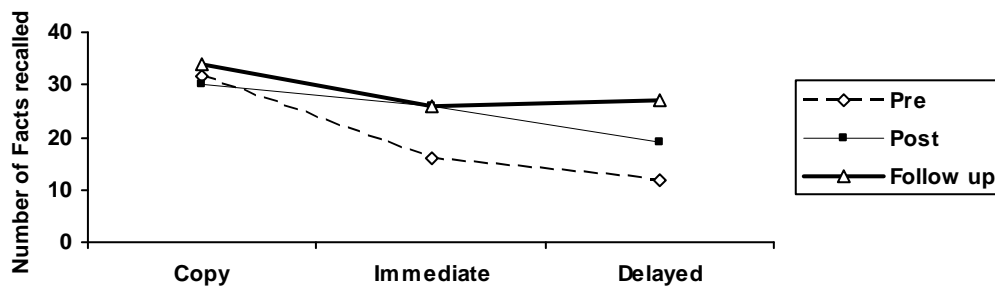
Note: NWR = non-word reading

Figure 5.9: HK's performance on verbal learning and memory measures



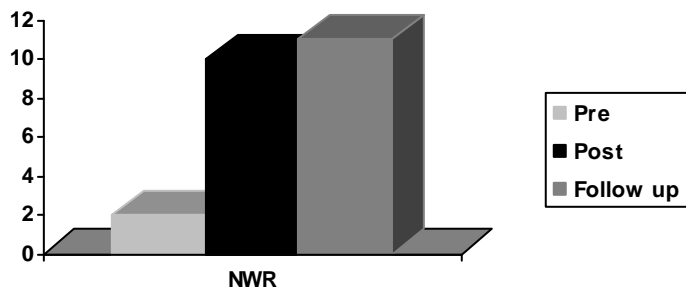
Notes 1 = number of words recalled on Trial 1 of AVLT; 2 = number of words recalled on Trial 2 of AVLT; 3 = number of words recalled on Trial 3 of AVLT; 4 = number of words recalled on Trial 4 of AVLT; 5 = number of words recalled on Trial 5 of AVLT; 7 = number of words recalled after 20 minutes' delay on AVLT.

Figure 5.2: HK's visual perception and visual across three assessments



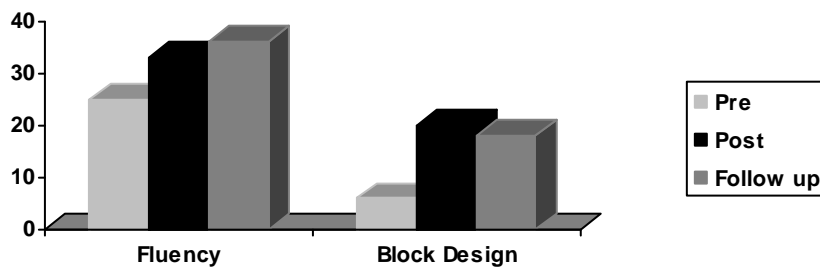
Notes: Copy = visual perception measured on Complex Figure Test; Immediate = immediate visual memory measured on Complex Figure Test; delayed = delayed recall on Complex Figure Test

Figure 5.3: HK's non-word reading performance across three assessments



Note: NWR= non-word reading

Figure 5.4: HK's fluency and block design performance across three assessments



### **5.6.1 Real Word Reading and Non-word Reading**

HK reading score place him above the mean score of the NP group mean at pre-assessment. However, his reading scores at post-reading improved and were comparable to the mean for the NC group. His score had further improved by the time of the follow-up assessment. At the initial (pre-) assessment, HK read 443 words accurately. The NC group mean was 511.65. At the post-intervention assessment, HK was able to read 540 words accurately; at follow-up, he could read 548 words accurately. HK was thus able to read at a level that was higher than the group mean of the NC group after intervention, and this lead had further increased three months after intervention.

HK's non-word reading performance was similar to his real word reading performance. HK could read only two non-words before intervention. At post-assessment, he could read 10 non-words from the same list; the NC group mean was 11.85. At follow-up, HK could read 11 non-words. Thus, his word-decoding abilities improved after the intervention and HK had maintained this gain three months after intervention.

### **5.6.2 Neuropsychological Functioning**

HK showed improvement on most of the neuropsychological parameters after intervention (see Table 5.5). Initial assessment did not reveal deficits in his verbal and visual working memory. HK had improved his scores on these measures at post-intervention assessment, and achieved further gains by the time of the follow-up assessment. HK's working memory scores were higher than the NC group mean at follow-up. His verbal fluency, along with his block design skill, showed an increase from the pre-intervention assessment through to the post-intervention assessment and

then on to the follow-up assessment (Figure 5.12), indicating that his executive functioning improved after intervention and that he was able to maintain this gain three months after intervention. A similar trend was noticed for both his verbal and visual memory. HK made significant gains in his delayed recall trial on both the AVLT and CFT measures at post-intervention and follow-up, suggesting improvement in his verbal and visual memory.

Table 5.5: HK's neuropsychological functioning across three assessments

Sl. No.		HK (pre)	HK (post)	HK (follow-up)	NC (N = 20)
1	Fluency	25	33	36	22.5
2	Digit forward	9	11	11	8.45
3	Digit backward	5	5	7	5.25
4	Digit span	10	11	12	9.6
5	Spatial span F	7	6	9	7.8
6	Spatial span B	7	5	6	6.6
7	Spatial span total	10	9	10	10.4
8	Stroop W	72	67	64	78.4
9	Stroop C	50	48	46	51.9
10	Stroop CW	23	29	24	28.3
11	Block Design	6	20	18	24.6
12	Colour Trail A	124	49	114	76.85
13	Colour Trail B	173	181	187	135.15
14	AVLT 1	5	8	7	6.95
15	AVLT 2	10	9	12	9.3
16	AVLT 3	9	10	12	10.45
17	AVLT 4	11	12	13	11.8
18	AVLT 5	13	14	14	11.6
19	AVLT-total	48	58	60	50
20	AVLT-delay	7	13	13	10.8
21	CFT-copy	31.5	30	34	34.6
22	CFT-imm	16	26	26	24.25
23	CFT-delay	12	19	27	24.85

*Notes:* Fluency = total words generated across three trials of Controlled Word Association; Digit backward = backward series of digit span; Spatial forward = score on forward series of Corsi Block Tapping Test; Spatial backward = score on backward series of Corsi Block Tapping Test; Spatial span = total score on Corsi Block Tapping Test; CTA = Colour Trail Form A; CTB= Colour Trail Form B; Stroop-C = Stroop Colour-Word Interference Test, colour trial; Stroop CW = Stroop Colour-Word Interference Test, colour-word trial; Verbal Learning = AVLT; Complex Figure-copy = score obtained on copy trial of Complex Figure Test; Complex Figure-imm = immediate recall of the Complex Figure Test; Complex Figure-delay = score obtained on delayed recall of CFT

A parental report collected at the three-month follow-up assessment showed that HK had shown good improvement in his behaviour and his academic record. The major change his parents noticed in him was that he was more co-operative during study periods. He was willing to sit longer with his books/homework and studied harder for tests and examinations; his parents no longer had to constantly remind him to do this. He appeared interested in taking responsibility. Overall, his parents felt that he was showing age-appropriate behaviour. His grades in school improved and he passed Standard 6 with



an aggregate of 55% (B+ grade) in all subjects. His reading was faster and his notes were complete, although his writing continued to be slow and clumsy but was better than before. His ability to understand concepts, even in subjects such as mathematics and science, was better. Certain behavioural problems had continued to persist, but were of a lesser degree. His impulsivity had not completely disappeared, but was less apparent. His parents said they could now get HK to control impulses by bringing them to his notice. Overall, HK's parents were satisfied with the progress HK had made since taking part in the intervention programme.

## **5.7 DISCUSSION**

HK's profile, at the pre-intervention assessment was suggestive of difficulties in reading and spelling difficulties. His parents reported of behavioural problems. HK was then provided neuropsychological intervention for 20 sessions across a span of 3.6 months. Intervention studies show improvement on tasks for which children receive training. However, generalisation to other cognitions not addressed in the training and the sustenance of this improvement over time is considered proof of the success of an intervention. HK showed both task-specific improvement and generalisation of functions after intervention.

In regard to the first aspect—improvement—the tasks that HK received training on and improved in included letter cancellation and shading ( tasks given for attention), phonemic fluency, temporal sequencing of material, and verbal memory and working memory. Practice and hierarchical placing of task difficulty were presumed to be instrumental in bringing about HK's improved performance on these tasks. This outcome

probably establishes the fact that training on specific tasks over a period of time with repeated presentations improves functioning on those tasks (practice effect).

The second aspect, generalisation to other tasks, was verified through assessment on neuropsychological tests. The battery selected covered cognitive abilities that were addressed in the intervention programme and some which were not addressed in the intervention. Phonological awareness and reading (of real words and non-words) and spelling abilities were also assessed. On the post-intervention assessment, HK showed improvement in his reading, spelling and behaviour, and had maintained this improvement three months on, at the time of the follow-up assessment. Significant gains were seen on non-word reading, passage reading, fluency, working memory (verbal and visual) and verbal and visual memory. Improvement was seen largely on executive functions, such as fluency, working memory and planning and organisation (as seen on block design and the CFT copy task). In addition to test and task improvement, HK showed improvement on reading passages and non-word reading.

On set-shifting abilities (Colour Trails A and B) and interference control, HK showed improved functions at the post-intervention assessment. However, this improvement was not sustained at the follow-up assessment. His performance on these two tests remained below the NC group mean on the follow-up assessment. Thus, these two abilities did not show improvement that could be sustained across the few months from the post- to the follow-up assessment.

The intervention programme was hypothesised to improve executive functions such as attention, scanning, fluency, organisation and planning of information, working memory and verbal memory. The training was based on the knowledge that when training

is given using tasks targeting specific functions over a period of time, it is hypothesised to improve those functions (Robertson & Murre, 1999; Scholberg & Mateer, 1989). Because the literature points to the presence of executive function deficits in children and adults with reading disorder (Howard et al., 2006), the intervention programme aimed to improve executive functions in these children on the premise that reading would also improve given that these cognitive abilities are hypothesised to sub-serve larger cognitive activities such as reading.

Individuals with executive function impairments display problems in starting and stopping, making mental and behavioural shifts relative to paying attention, and awareness of self and others. Component processes hypothesised to support executive control include activation/drive systems, inhibitory control, working memory, interference control, prospective memory and self-monitoring/regulation (Scholberg & Mateer, 1989).

The tasks chosen in the intervention programme covered a number of cognitive abilities subsumed under executive functions. When the demands of increasing difficulty levels are placed on the frontal lobes, this process possibly activates the functioning of the executive system. Hierarchical training exercises designed to provide structured opportunities to practise are hypothesised to strengthen particular cognitive skills. Repetition is hypothesised to be critical to the re-automatisation of such abilities (Scholberg & Mateer, 1989). The basic premise for the intervention programme is repeated practice of tasks arranged in a hierarchical fashion to bring about functional connectivity. This connectivity probably leads to automatisation of functions within the target circuits and then is hypothesised to lead to automatisation of target cognitive

functions (Scholberg & Mateer, 1989). The automatisisation of those regions involved in reading lead to automatisisation of reading that is thought to be a secondary function within those circuits. Recent research (Jaeggi, Buschkuhl, Jonides, & Perrig, 2008) indicates that when working memory is enhanced through training, fluid intelligence was also thought to improve.

Examination of HK's assessment profile before and after intervention confirms that training improved his executive functions and strengthened functional connectivity, resulting in an overall improvement in HK's cognitive abilities, reading skill, behaviour and emotional status. His social behaviour improved, and generalisation to other academic activities was also noticed, despite these aspects not being targeted through the intervention programme. We could argue that repeated assessment will lead to familiarity with the test material and thereby result in improvement. However, HK's improvement was not uniform across all tests and was not sustained on two neuropsychological tests at follow-up intervention. Thus, the practice effect may not have been the primary cause of better performance.

Before intervention, HK had few deficits on the neuropsychological tests, and only two subtests on the QUIL showed low performance. HK was functioning at a level higher than that of the rest of the children in his intervention group, and was comparable to the non-disabled group on several neuropsychological tests and phonological awareness tests. After intervention, he showed improvement in most areas, and his performance was also above the NC group mean for neuropsychological tests and reading. It therefore appears that the deficits in HK were restricted to a few aspects of cognitive abilities only.

Studies show that children with milder disability have fewer deficits on neuropsychological tests (Crawford, Kaplan, & Dewey, 2006). It is hypothesised that when training is accurately targeted to address only those aspects cognitive functions that were found to be deficit in HK, he showed an overall improvement in trained as well as untrained aspects of functioning. We hypothesise that the strengthening of executive functions caused HK to use (compensatory) strategies that were not available to him earlier when reading or spelling. These strategies resulted in better overall academic performance and specifically in reading. The results of the intervention programme for HK establish that when only a few deficits are identified in an individual with reading disorder, intervention targeting specific cognitions leads not only to improvement of those functions but also generalises to other cognitions sub-served by those cognitions.

The parental report indicated that some behavioural difficulties persisted even after the intervention. These included poor and slow writing and low impulse control. Ability to write to dictation and copy from the blackboard or a text probably requires the smooth functioning of several cognitive abilities: visual scanning, motor co-ordination and intact working memory to hold information in the mind while writing it out. In addition, phonological awareness aspects (spelling and word decoding in particular) are hypothesised to be intact for this activity to be carried out with accuracy and speed.

Because HK continued to show deficits in visual scanning, set-shifting and interference control (scores on Colour Trails A and B and the Stroop Colour-Word Test), we postulated that these activities could be impaired or effortful, especially as improvement had not generalised to these two tests on the neuropsychological battery. Also some remnants of the behavioural problems could be explained by the presence of

inhibition control deficits. The intervention programme probably did not include tasks that were specific enough to bring about change on these cognitive abilities, a matter that needs to be addressed in further intervention programmes of this kind.

## CHAPTER VI

# GENERAL DISCUSSION

### 6.1 INTRODUCTION

Phonological awareness deficits have been known to be associated with reading disorder. Several studies provide evidence that PA deficits are present in children and adults with reading disability (Frackowiak et al., 2004; Ramus, 2003). Providing remedial training for these deficits is known to be associated with improved reading abilities (Gillon, 2004). The deficit profile and improvement patterns, however, have not been uniform. The current study hypothesised that the anatomical regions associated with reading subserve other cognitive functions. Dysfunction seen in reading possibly suggests dysfunctions in those circuit(s) and thus point towards probable multiple symptom profiles. Addressing only the phonological processing deficits therefore could result in only partial remediation of deficits.

This thesis, in a series of three studies, set out to highlight that presence of cognitive and phonological awareness deficits can explain presence of reading disorder. Because several cognitive processes are involved, the disorder appears multi-faceted, with phonological awareness being only one aspect of this complex picture. Addressing only the phonological awareness results in partial remediation only, explaining why some individuals continue to show deficits despite undergoing remediation for phonological awareness. We also proposed that these cognitive deficits probably interfere in various

domains of functioning, in addition to reading, if left untreated. Hence, remediation of all the cognitive deficits could possibly be necessary in order to effect improvement across all domains.

Reading disorder is prevalent in all cultures and across different languages (Karanth, 2008). The influence of the language that the child has to learn to read is significant in the developmental process. The educational setting in which the child is expected to perform adds another dimension to this multifaceted disorder. We therefore attempted to explore the presence of phonological awareness and neuropsychological deficits in children with reading disorder in children from New Zealand and from India. Establishing presence of reading, neuropsychological and phonological deficits in children from diverse cultures and effort to improve their reading through structured phonological awareness skills were vital aspects of this study.

## **6.2 ESTABLISHING EXECUTIVE FUNCTION DEFICITS**

The thesis was carried out as a series of three studies. The first study aimed to assess children in New Zealand with specific reading disorder before and after phonological awareness intervention. Four children (age range, 8 to 14) with specific reading disorder were assessed on neuropsychological measures before receiving phonological awareness training. Their performance on neuropsychological measures was compared to the performance of four children (8- to 10-year-olds) without reading disorder on the same measures. After intervention, the performance of the children with reading disorder was compared with their pre-intervention performance. The findings suggested that executive deficits were present in the reading disability group before phonological awareness intervention. After intervention, improvements were noticed in neuropsychological



functioning along with phonological awareness. It was hypothesised that persisting executive function deficits in this group could be responsible for persisting comprehension difficulties.

### **6.3 COMPARING PHONOLOGICAL AWARENESS INTERVENTION AND NEUROPSYCHOLOGICAL INTERVENTION**

In the second study, an attempt was made to address the executive functions deficits by developing a neuropsychological remediation programme and comparing its effectiveness with a remediation based on phonological awareness. The group of children who participated in this study ranged in age from 10 to 13. Through neuropsychological remediation based on Luria's "functional reorganisation" and our current understanding of neural plasticity, an attempt was made to develop a neuropsychological remedial programme. Repeated practice of tasks arranged in a hierarchical fashion is known to achieve automaticity in cognitive processes (Schneider 2003; Schneider & Shiffrin, 1979). The automatising of these cognitions is believed to enhance the neural plasticity within the target areas.

We proposed that the plasticity would probably result in enhanced reading, as reading is hypothesised to be a secondary function within the targeted cognitive processes. Processes in reading that were effortful earlier due to improper functional connectivity could probably lead to problems in comprehension and speed of reading. We also proposed that, subsequent to neuropsychological remediation, these processes would become automatic, leading to increases in aspects of reading. We furthermore considered that the assessment of associated clinical comorbidities before and after remediation of reading would throw light on the relationship between reading and other clinical features.

The literature shows that reading disorder was initially studied in English-speaking countries and that the assessment focused on reading ability in English. Over the past several years, study of reading disorder has spread to several non-English speaking nations (Karanth, 2008). Understanding stemming from research across linguistically different nations suggests that incidence of specific reading disorder does not disappear in other languages but that incidence rates differ depending upon the structure of the language.

In a nation such as India, where all children are exposed to more than one or two languages in their day to day functioning, assessing and establishing prevalence of specific reading disorder becomes a daunting task (Kapur, 2008; Karanth, 2008). Questions about the relevance of using tests meant for English-speaking children have been raised. Studies report that typically developing children studying in English-medium schools demonstrate adequate phonological skills in English (Prakash & Rekha, 1992; Prakash, Rekha, Nigam, & Karanth, 1993; Prema, 1998). However, studies exploring the presence of phonological awareness deficits and their contribution to reading disorder had not been attempted. We therefore considered that studying the phonological processing deficits and providing phonological intervention for children with reading disorder in India would throw light on the phonological processing abilities of children with reading disorder in diverse educational settings.

The nature of the education system in India is complex (Kapur, 2008), and high demands are placed on children to perform in school. Particularly high demands are placed on reading, remembering facts and writing skills. As such, there is a need to consider a remedial programme that helps address several related issues in addition to the

phonological processing deficits known to be associated with reading disorder in children from the West.

In order to achieve both goals, we assessed a group of 20 children (10 to 13 years of age) with reading disorder (the RD group) from India on phonological awareness and neuropsychological tests. The performance of the RD group was compared with that of 20 normal control children (NC) who did not have any reading difficulties. The NC group was comparable in age and education level with the RD group.

The comparison showed that the two groups differed on phonological awareness and executive functions, findings in keeping with findings from the previous study, which showed that the children with reading disability had phonological awareness (PA) difficulties and neuropsychological deficits, such as executive functions, verbal and visual memory and visuo-spatial construction abilities. The PA difficulties were non-word reading, spoonerism, syllable identification, phoneme segmentation and deletion and rhyming skills. Both findings accord with current literature that points to the presence of PA difficulties (Gillon, 2004; Shaywitz & Shaywitz, 2005) and neuropsychological deficits in executive function (Protopapas, Achroniti, & Skaloumbakas, 2007). Thus, the first aim to establish presence of phonological and neuropsychological deficits in children with reading disorder in India was met.

The 20 children with reading disorder were then randomly divided into two groups of 10 children each. One group (PA) received phonological awareness intervention while the other received neuropsychological (NP) intervention. The two groups received 20 sessions of intervention over three to four months. Assessment of phonological awareness and neuropsychological functions was once again carried out after the 20 intervention

sessions. The post-intervention assessment revealed that both groups improved in their reading, phonological awareness and neuropsychological functioning. In addition, they both displayed significant improvement in their non-word reading abilities. The PA group showed improvement on verbal fluency, visual scanning, verbal memory and visual memory. The NP group improved on verbal fluency, working memory, inhibition control and visual memory. The phonological skills of the children in both intervention groups also improved. The PA group showed improved non-word spelling, syllable segmentation and phoneme detection; the NP group showed improvement in spoonerism and tracking change in syllable sounds using blocks. The interventions also possibly had an impact on the children's emotional wellbeing. The PA group displayed increased self-concept while the NP group displayed reduced anger, anxiety and depression scores after the intervention.

The results of the intervention study indicate deficits in inhibition, working memory, set-shifting and verbal fluency in children with reading disorder and align with the findings of previous studies that point to the presence of cognitive deficits outside the realm of phonological processing in poor readers. Presence of executive deficits in this population also has been reported in earlier studies (Bosse et al., 2007; Lazar & Frank, 1998; Protopapas et al., 2007).

Functionally, the executive functions are hypothesised to be controlled by the frontal lobes, especially the pre-frontal regions of the brain. These functions are not known to be directly associated with phonological processing but are hypothesised to play a supportive role in processing sounds. The intervention study therefore helped to establish that cognitive deficits and phonological awareness difficulties probably exist in

children with reading disorder. Providing neuropsychological intervention proved effective in improving reading and word decoding abilities as did intervention focusing on phonological awareness. Both interventions had a differential effect on the emotions of the participants.

#### **6.4 THREE-MONTH FOLLOW-UP STUDY**

In the third study conducted for this thesis, the 20 children who received intervention for reading disorder were assessed on reading and neuropsychological and phonological measures. The aim was to find out if the improvements noticed after the intervention could be sustained over a period of time and whether there would be any further improvements in the reading skills of the children.

The follow-up study assessed all 20 children with reading disorder (from the previous study) three months after the conclusion of the intervention programme. In the three months between the end of the intervention and the follow-up assessment, the children attended regular school. They did not receive any additional inputs, and they were not given support of any kind for their reading and spelling difficulties. All 20 children were assessed on reading, neuropsychological tests and some phonological awareness tests.

While the PA group improved on digit span, set-shifting and inhibition control and verbal memory in addition to reading and non-word reading and phoneme segmentation, the NP group exhibited improved attention, working memory, verbal learning and visual perception at the follow-up assessment. The improvement in the scores on the measures used to assess these skills were either statistically significant or were approaching significant levels compared to the comparable pre-intervention scores. However,

comparison of the scores on these measures at the pre- and the post-interventions produced no significant differences.

Repeated measures analysis of variance (RMANOVA) indicated that inhibition control displayed a significant interaction effect for the PA group while verbal fluency displayed a significant interaction effect for the NP group. This finding suggests that the phonological awareness intervention probably improved inhibition control over time in comparison to the neuropsychological intervention. The neuropsychological intervention, on the other hand, possibly significantly enhanced verbal fluency over time in comparison to the phonological awareness group. Both groups showed improvements in executive functions, verbal memory and visual memory across the three assessments in addition to reading.

## **6.5 PHONOLOGICAL AWARENESS INTERVENTION**

The PA group improved on reading, word decoding and phoneme segmentation abilities, findings in keeping with the present literature which shows that phonological awareness training improves phonological processing abilities and improves reading accuracy (Frackowiak et al., 2004; Gillon, 2004). In addition to this improvement, the intervention positively influenced related cognitive abilities involving visuo-spatial working memory, set-shifting and interference control, all of which can be subsumed under the executive function. Executive functions are known to be associated with the dorso-lateral prefrontal cortex and the anterior cingulate cortex (Robertson & Murre, 1999).

Research findings suggest that the nature of the remedial educational intervention is critical to successful outcomes in children with reading disabilities and that the use of an

evidence-based phonological reading intervention facilitates the development of those neural systems that underlie skilled reading. The work of Shaywitz and colleagues (2004, 2005) indicates that a phonologically based reading intervention leads to the development of neural systems both in anterior (inferior frontal gyrus) and posterior (middle temporal gyrus) brain regions. Their 2004 study showed that the nature of the intervention is crucial in bringing about changes in the reading (word-decoding skills) and in the neural structures responsible for reading. Phonological processing abilities are hypothesised to be associated with the inferior frontal lobes and the superior and posterior temporo-parital regions (Frackowiak et al., 2004).

In the current study, the intervention possibly brought about changes not only in the functions of phonological processing abilities, but also in the functioning of the executive functions. The dorsolateral prefrontal cortex (DLFPC) mediates executive functions of organisation, planning, set-shifting and working memory while the anterior cingulated cortex is responsible for inhibition and interference control. The current study indicates that other cognitive functions not directly associated with reading possibly showed improvement in response to phonological awareness intervention.

Phonological awareness intervention is a specifically targeted intervention aiming to improve phonological skills and is known to be associated with improved reading abilities. In addition, the significant improvement in the executive functions of set-shifting and interference control (which were not targeted in the intervention) suggest that the intervention program probably also improved the cognitive skills that are known to play a supportive role in the process. Lovett and Steinbach (1997) have proposed that because reading is a complex process, it requires intact functioning of other cognitive

abilities such as attention and executive functions. We accordingly hypothesised that success on tasks within the programme would depend on intact executive functions. Improvement on tasks such as tracking sound changes in syllables using blocks possibly requires the child to hold the previous sound “online” while attempting to recognise the new changed sound. Improvements in tracking ability thus could depend on and possibly lead to improvement in working memory and interference control, because the child has to ignore irrelevant sounds and focus on relevant ones.

For improvements to occur in reading, research indicates improvements in phonological skills. Phonological skills, in turn, are hypothesised to require intact executive functioning. Therefore, we consider the improvements that we noticed on specific neuropsychological functions could be as a result of the nature of the training provided. We took the maintenance of the improvements (in reading, tracking ability and executive function) across time as further support for the premise that improved associated cognitive functions are required to sustain improvements in reading over time. Further studies, possibly involving electrophysiological and functional neuroimaging might help us corroborate and better understand these findings.

## **6.6 THE NEUROPSYCHOLOGICAL INTERVENTION PROGRAMME**

We also attempted explore the effects of other intervention programmes on reading. For this purpose, we developed a neuropsychological remediation programme aimed at improving attention, executive functions (such as working memory, organisation and planning and verbal fluency), and verbal learning and memory and implemented it with 10 children with reading disorder. The training programme targeted the specific cognitive



abilities of attention, executive functions and verbal memory. Improvements were noticed in these functions after 20 intervention sessions.

The rationale for the intervention was that the cognitive skills chosen for training were hypothesised to play an associative role in the reading process. Deficits in these cognitive abilities have been implicated in previous studies. We hypothesised that if executive functions are required in the process of reading, and if children with reading disorder have deficits in executive functions, then intervention for reading must also target executive function deficits in order for improvements in reading to be sustained.

Post-intervention assessment revealed that the neuropsychological intervention group showed improvements in attention, working memory, set-shifting, verbal memory and visuo-spatial perception. Improvements were also noted in reading, non-word reading and phoneme segmentation. The results furthermore provided evidence that children with reading disorder possibly improved in attention, executive functions and verbal memory for which they received training. Visual perception also improved, while reading and non-word reading showed significant change after the intervention. The improvements in all areas were maintained over time, as established by the results of the three month follow-up. In addition, emotions such as anger, depression and anxiety showed a reduction across the time period spanning the pre-intervention and the follow-up assessment. Taken together, the findings probably suggest that improvements in neuropsychological functions, such as executive functions, attention and verbal memory, probably result in improvement in reading and word-decoding abilities.

The NP group showed improvement on working memory, verbal fluency and verbal learning. These functions are known to be associated with the dorsolateral

prefrontal cortex (DLFPC) (Robertson & Murre, 1999). Also, improved reading, non-word reading, visuo-spatial perception and verbal memory are implicated in the functioning of the posterior brain regions, namely the anterior and superior temporal and anterior parital lobes (Joseph, 2000). These regions are hypothesised to be associated with phonological processing abilities (Shaywitz et al., 2002; Temple, 2002). The improvements noticed in reading and non-word reading abilities suggest that phonological awareness probably improved in the children in the NP group even though these abilities were not directly trained during the intervention. We hypothesised that improvements in reading are associated with improvements in executive functions. The findings for the NP intervention group also point to the reverse—that improvements in executive functions could possibly result in reading and phonological awareness. Thus, the study possibly points to a reciprocal process between reading and executive functions. Training one leads could probably lead to improvements in the other.

The study has helped to establish that executive function deficits are present in children with reading disorder. Specific training targeting phonological awareness probably leads to improvements in reading and executive functions. A general training programme targeting improvements in executive functions can possibly bring about improvements in reading—improvements that are sustained over time. Although the nature of tasks differed in the two programmes, the children in both groups showed improvements in their reading and non-word reading performance. However, further studies directed at studying the interventions offered to different groups would help us better understand this aspect.

## 6.7 CASE STUDY

Having been screened and identified as having reading disability, HK (11.8 years of age) was selected for inclusion in the intervention study and was randomly assigned to the neuropsychological intervention programme (NP). After the initial screening and pre-treatment assessment, HK received a neuropsychological intervention comprising 20 sessions across a span of 3.6 months.

At the time of the pre-intervention assessment, HK had reading and spelling difficulties and behavioural problems. Neuropsychological deficits were found in interference control, set-shifting, verbal memory and visual memory. On most of the other neuropsychological functions, he was above the mean for the NP group and close to the mean for the control group (NC). Phonological deficits were noticed on non-word reading and spoonerism. After intervention (post-test assessment), it was evident that he had made gains in working memory, fluency, verbal and visual memory and visuo-spatial perception, and his reading score was higher than the mean score for the NP group (at post-treatment assessment) and the NC group. His on non-word reading improved from a raw score of 2 before intervention to 10 at follow-up assessment suggesting that the scores continued to increase after intervention. (The mean score of the control group on this test was 11.58) All improvements had been maintained by the time of the three-month follow-up. A report from HK's parents indicated that HK displayed positive behavioural changes after the intervention. (Behaviour problems associated with study time had been the most disturbing problem for the parents.) His academic records also showed, an improvement and he was able to pass in his final examination with a B+ average in all subjects. In summary, the case study helped us establish that use of a more

general intervention programme targeting the cognitions known to be associated with reading, such as executive functions, can produce improvements in reading, phonological awareness, neuropsychological functioning and behaviour.

## **6.8 LIMITATIONS**

The programme of study informing this thesis was conducted on 20 children with specific reading disorder. Their performance on various measures was compared with the performance on these measures of 20 children without reading disability. However, this body of research has several limitations:

1. One hundred and twenty-five children were screened for the presence of reading disability. From this pool, 20 children with reading disability were chosen for one of two intervention programmes. Ten children were thus assigned to each programme, making for a small sample size within each programme and thereby limiting generalisation of the main findings of the study.
2. Several tests used in the study did not have Indian norms, which meant that normative data was not available for them. However use of a normal control group comparable in age and education helped overcome this limitation.
3. Language difficulties are often associated with children with reading difficulties. In the current study, we were not able to assess these aspects in the children with reading disability. Assessment of their language abilities would have helped us better understand the reading process and associated improvements.
4. The normal control group was assessed only once in the study while the reading disorder group was assessed three times. Assessing the control group across two

time periods would have helped rule out possibility of influence of a practice effect in the reading disorder group. In addition, assessment after six months would have helped us identify the normal developmental process in the cognitive functions of the control group. Because the control group was assessed only once, the role of normal development of cognitive process could not be established. However, studies have shown that developmental spikes in this age group occur at one-year intervals only. We can therefore assume that the changes in cognition noticed in the intervention group occurred because of the intervention.

5. The neuropsychological tests chosen were not inclusive of planning and organisation. A wider range of tests, covering other executive functions, would have provided better insights into the neuropsychological deficits and their improvements after intervention.
6. The reading test used in the study did not have quantifiable norms, which meant that extent of disability could not be quantified. The tool is used primarily for clinical diagnosis rather than for research purposes. The tool is therefore useful when one is trying to assess the presence of reading disorder. However, quantification of the difficulties is not possible. As a consequence, the exact amount of improvement could not be established, which is why the number of words read accurately was assessed to establish improvement in reading ability.
7. Presence of electrophysiological or functional imaging components would have helped to establish the anatomical regions involved in the reading process, in the reading disability and in the improvements noticed in the reading disorder groups in response to intervention.

Despite these limitations, the study has several clinical implications. These are described in the next section. Further research in several areas would answer vital questions raised in this study.

## **6.9 IMPLICATIONS OF THE FINDINGS**

The thesis, across a series of three studies, has helped with identification of the presence of neuropsychological deficits in children with reading disability. The presence of neuropsychological deficits in the form of executive function deficits, found in the children with reading disorder who participated in the studies, is in keeping with the knowledge evident in existing literature. Studies have found working memory and interference control deficits in children with reading disability. Earlier literature mentioned individual variations in deficit profiles and in response to intervention programmes. The establishment of associated neuropsychological deficits helps understand this complex picture. Some studies have pointed to the absence of phonological awareness deficits in children with reading disability (Ramus, 2003) while others have reported a failure to show generalisation of improved phonological awareness inputs to better reading skills.

In the Indian educational setting, high demand is placed on writing and test performance. Children are periodically assessed in the written form for retention of information taught in class. This requires intact neuropsychological functioning, such as working memory, verbal fluency and writing skills in addition to reading and spelling. Providing intervention in such a setting needs to be specific to address the deficits associated with reading. In addition, the intervention needs to cater to the diverse needs

of the child in a demanding educational setting. The results of the study show that a specific intervention (phonological awareness) and a more general intervention (neuropsychological) both successfully enhanced reading skills—improvements that were maintained over time. In addition, associated cognitive abilities improved, suggesting that both intervention programmes not only addressed associated functions but also specifically targeted reading and phonological skills.

Intervention focusing on enhancing phonological awareness resulted in improved neuropsychological functioning in the PA group. Enhancing neuropsychological functioning was also noticed to be associated with enhanced phonological processing skills in the NP group. These findings indicate a possible reciprocal relationship between phonological processing and neuropsychological functions in the context of reading disorder. We accordingly hypothesise that intervention programmes addressing both deficits are probably more effective across different populations than are interventions that address one set of cognitive skills to the exclusion of the other. However, more studies conducted across different populations and with much larger samples than the one used in the present body of work are required to substantiate this hypothesis.

The findings of the study could be explained by the probable presence of executive function deficits. If executive functions are not addressed in the intervention programme, the persistent deficits could possibly affect the reading skills. We therefore propose that the presence in poor responders of persistent executive function deficits could be associated to phonological interventions.

These findings have important clinical implications.

1. If training aspects of executive function is incorporated into a reading remedial programme, it would be possible to address the needs of different kinds of children with specific reading disorder.
2. Accurately identifying the executive function deficits in specific reading disorder accounting for the individual differences in the deficit profile is a common problem within this population. A single remedial programme with only specific inputs might result in improvement in only a few individuals.
3. Incorporating other associated aspects into a remedial training programme will have better outcome implications for a larger number of children with reading disorder.
4. Using a combination of intervention programmes would be beneficial to a larger number of children than would using only one kind of intervention.

These implications are highlighted by the neuropsychological intervention programme and the case study described above. Further studies, with better controlled conditions across different populations and age groups, would further illuminate this aspect.



## CHAPTER VII

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