ABSTRACT

The focus of this study is to investigate the transient deficit hypothesis in relation to children who experience Specific Reading Disability (SRD). Specific Reading Disability is defined as a child of normal intelligence (or above) who has no behavioural or emotional problems but their reading age is two or more years behind their age group. The transient deficit hypothesis is a major approach in vision reading research used to account for the differences found between normal readers and children with SRD. This approach proposes that two pathways are involved in visual processing: the transient pathway is suggested to be sensitive to global features, movement, peripheral information and low spatial and high temporal frequencies; and the sustained pathway is proposed to process central features, stationary images, colour and high spatial and low temporal frequencies (Lovegrove, 1993). Transient deficit hypothesis suggests that a weak transient channel can adversely affect the two systems combining properly during reading. A sluggish transient channel may cause a superimposition of letters, causing the SRD child to see letters that appear to overlap (Lovegrove, 1993).

This study investigated differences in visual processing between three groups (Chronological age-matched, SRD, and Reading age-matched) of 18 children. The transient deficit hypothesis was examined in the first experiment by using the global precedence paradigm. In Experiments 2 and 3, the sensitivity of the retina and the effect of variation of the size of stimulus were explored. Secondary to these experiments is the fourth experiment where the influence of incongruent processing on the visual processing of SRD children was explored.

The aim of Experiment 1 was to compare the performance of SRD to the performance of normal readers in processing whole and parts of a compound stimulus. Following the transient deficit hypothesis, SRD children should have shown difficulty in processing the global stimulus in comparison to the local aspect of a stimulus. The results of Experiment 1 showed that the global level was detected faster than the local level by all three experimental groups. The reaction times (RT) of SRD were significantly slower (77 milliseconds, $p < 0.05$) than the Chronological age-matched group, and the Reading age-matched group's times were significantly slower (96 milliseconds, $p < 0.05$) than those of the SRD.

Under the transient deficit hypothesis it could be expected that if SRD children have a weak transient channel this may lead to a deficit in processing peripheral information. Experiment 2 found that for all three groups, as stimuli were presented further from the fovea, the RT patterns best fitted with an increasing linear function. The Chronological age-matched group RT was faster than the SRD group (187 milliseconds, $p < 0.01$), and SRD group RT was faster than the Reading age-matched group (31 milliseconds, $p < 0.10$).

The purpose of Experiment 3 was to ascertain whether SRD children would have greater difficulty in processing larger stimuli as compared to smaller stimuli. By following the spatial frequency theory it is suggested that low spatial frequency could be associated with larger stimuli, and this may lead to a slower performance by SRD. The results of

Experiment 3, indicate that all three groups processed larger stimuli more slowly than they did smaller stimuli. Results for all three groups formed decreasing logarithmetic functions. SRD were significantly behind the Chronological age-matched (70 milliseconds, $p < 0.05$), and significantly in front of the Reading age-matched group (140 milliseconds, $p < 0.01$).

From Experiment 4, it appears that conflicting information between the local and global levels, results in the global having an inhibitory influence on responding to the local level. Similar to Experiment 1, the pattern of results to global and local levels formed quadratic functions. The consistent stimuli were detected faster than the inconsistent stimuli in all three groups. In other words, SRD were not significantly different from the other two reading groups in response to inconsistent and consistent stimuli. The inconsistency of stimuli did not have a detrimental effect on their performance.

Results from the four experiments show that SRD children do not have any difficulties in processing wholes in comparison to parts, or problems in processing peripheral visual information in comparison to central, and no deficits in processing low spatial frequencies in comparison to high. Additionally in regard to incongruent information, SRD children did not show any significant differences from normal readers. However, the SRD children were significantly slower in the processing of any type of visual information in comparison to the Chronological age-matched children.

In conclusion, the results show that a low-level transient deficit did not lead to difficulties for SRD children in processing global information, stimuli at peripheral locations, and large and inconsistent stimuli. The findings do not support the transient deficit hypothesis in the sense that the transient sub-system is suggested to be associated with global level processing, low spatial frequencies, peripheral vision and incongruent information. However, the results of this study confirmed the transient deficit hypothesis in a sense that the transient sub-system is suggested to be associated with high temporal frequency. In this study, the slower pattern of RT for the SRD group could be related a deficit in visual processing of SRD individuals, or the difference in average IQ between the SRD group and the Chronological age-matched group.

AN EXPLORATION OF

TRANSIENT DEFICIT HYPOTHESIS

IN SPECIFIC READING DISABLITY

A Thesis Presented to

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AN EXPLORATION OF TRANSIENT VISUAL HYPOTHESIS IN SPECIFIC READING DISABILITY

RENEE A. HOP YEK

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DECLARATION

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

Renee Hop Yek

Renee A. Hop Yek.

CHAPTER 1: LITERATURE REVIEW

Reading is a prerequisite skill for most daily activities and is primary to lifelong learning. The ability to read is vital to cognitive, social and emotional growth (Neale, 1995). Reading is a complex skill that most children learn with adequate opportunity. While the ability to read is normally taken for granted, literacy is not as effortless as it first seems. Children who fail to read at normal levels, but who have normal intelligence and no significant emotional or behavioural problems are known as having dyslexia or Specific Reading Disability (SRD). Specific Reading Disability is typically defined as a disability where a child of normal intelligence (or above) who has no behavioural problems but a reading age of two or more years less the reading level expected on the basis of their chronological age (Evans, Drasdo, & Richards, 1994; Hogben, Rodino, Clark, & Pratt, 1995; Amirkhiabani & Lovegrove, 1999).

The concept of SRD has been controversial (Applebee, 1971; Stanovich, 1991). Research in this area has used the same definition to diagnose children with SRD, in order to make comparisons. However one of the exclusionary criteria disputed by reading researchers is that a child must have adequate intelligence (Stanovich, 1991). The controversies that surround the use of the term dyslexia are not considered in this thesis and from this point the SRD terminology is generally adopted. The very existence of SRD (Prior, 1989), its aetiology (Fletcher & Satz, 1979a; Vellutino, 1977) and its treatments remain debated (Hogben, et al., 1995). It is for these reasons the research interest in this area continues to grow.

There are two predominant positions on SRD: the phonological deficit hypothesis, and the visual deficit hypothesis. While there will be a discussion on the controversy in the vision research literature, the thesis focuses on the visual deficit hypothesis. Firstly, the thesis critically reviews the phonological deficit hypothesis and then examines three theoretical frameworks that are prerequisites to understanding the literature on visual deficits associated with SRD. First to be reviewed is the theoretical framework of spatial-frequency analysis. The processing of information from the eye to the brain is then addressed and this leads to a discussion of the transient and sustained sub-systems and how they relate to the visual act of reading. These three areas provide the framework for the transient deficit hypothesis. After the review of literature on processing of visual information in dyslexia, the research on integrating the two frameworks is examined. A review of the interventions used to assist SRD children is then conducted, which will be followed with four experimental chapters.

In continuation of this section a number of key studies that investigate some general characteristics of SRD children will now be discussed.

1.1 Characteristics of Specific Reading Disabled

1.1.1 Sub-types

Hogben et al. (1995) discussed whether reading disability should be seen as part of normal distribution of reading or as a pathological condition. Stanovich (1993) explained the notion of SRD as a continuum from the garden-variety poor reader, to average reader, and then to good reader. Stanovich (1993) also suggested that this continuum framework explains why the research has found a number of isolated deficits and sub-types that relate to SRD. It appears that the results of sub-group studies should be interpreted with caution as much of the research has used different methodological and analytical designs.

Ellis (1985) states that a multiple of factors may contribute to reading disabilities and an important factor to take into account is individual variation. Additionally, it has been argued that SRD is a heterogeneous category with distinct sub-types (Boder, 1973). This leads to the notion that different deficits might be involved with different sub-types and that reading problems should not be studied as a unitary disorder that has a single cause. Ellis (1985) states that once this notion is established, researchers must then agree on how heterogeneity should be measured.

Castles and Coltheart (1993) proposed a sub-type classification system where dyslexics were placed into two groups, surface and phonological. Surface dyslexics have difficulty with lexical procedures (reading at word level) and phonological sub-types have difficulty with phonological decoding (sub-lexical procedures). Their classification system is linked with the well-known dual route model of reading.

Bakker, Licht, Kok, and Bouma (1990) classified dyslexics into P-types (who depend on the right hemisphere and perceptual mode) and L-types (who conversely depend on the left hemisphere and linguistic mode). P-types remain fixed at the percept level, whereas L-types first employ linguistic strategies. Boder (1973) suggested that the normal reading process first depends on perceptual strategies and that linguistic strategies are critical later on. Despite the disagreements (to be discussed in Section 1.3.) on whether there is an SRD group with deficits in some aspect of visual processing, studies such as this one have found a visual deficit sub-group.

Boder (1973) subdivided SRD in terms of their reading ability, spelling performance and reading strategies. In this well-known study, Boder (1973) classified SRD children into three groups. The first and largest subgroup was the dysphonetic (67%). These children had difficulty breaking unfamiliar words into their phonemic components. Dyseidetic SRD was the second group making up 10%. They could pronunciate but continued to decode words when others would recognise the word by sight. The third group was the mixed dyseidetic-dysphonetic group and they account for the remaining 23%. This group was poor at both visual and phonologically mediated reading. Boder (1973) states that both the inability of dyseidetics to build up a sight vocabulary, and the inability of dysphonetics to sound out words, gives this third group the poorest prognosis.

While sub-type classification may be clinically useful it does not probe into scientific causes. Hogben (1996) states that sub-type classifications offer a snapshot of the dyslexic child at his or her present state of development. The end product of all this may tell very little about what went wrong in the first place. This may be the case, however, discussion of sub-types gives rise to the notion that SRD could be caused by a combination of deficits. It does appear warranted that research consider other factors such as auditory and visual deficits, as well as predominant linguistic factors in considering theories which attempt to account for SRD. Several researchers (Pirozzolo, 1981; Tallal, 1980) have found auditory sub-types of SRD. A number of key studies in the auditory modality, which have found supportive evidence of differences in processing between normal readers and SRD children, will now be reviewed.

1.1.2 Auditory domain

Although the present thesis focuses on vision research, reading research extends into the other perceptual senses. Farmer and Klein (1995) found that processing difficulty may be present in a number of sensory modalities. Studies that have investigated auditory factors vary from: Hicks (1981) who found a difference in visual to auditory conversion between SRD and other reading impaired, to Miles and Haslum (1986) who investigated the auditory recall of digits.

Poor readers have difficulty producing names in response to pictures or verbally labelling objects (Snowling, Van Wagtendonk, & Stafford, 1988), and they make more errors in doing so (Katz, 1986). Additionally, poor readers are also slower than normal readers in rapidly naming objects, letters, digits and colours (Bower & Swanson, 1991; Denckla & Rundel, 1976), and they cannot generate as many rhyming words as normal readers, and they are slower to produce them (Snowling, Stackhouse, & Rack, 1986).

Tallal (1976; 1980; 1984) has been most influential in researching auditory processing between SRD and normal readers and has found that SRD made greater errors than controls when information is rapidly changed during fast tones but no difference at slower tones. Using an auditory temporal-order judgement task and an auditory fusion task, Tallal (1980) found that when the interval was reduced, SRD performed worse than controls and that there was a highly significant correlation between auditory temporal measures and nonsense-word performance.

As stated previously, the research into visual reading deficits is carried out within two major positions: phonological deficit hypothesis and visual processing deficit hypothesis. The first approach to be discussed is the well researched and supported phonological hypothesis. It is the second position which is the focus of this study. The second hypothesis is the position adopted by Lovegrove and his colleagues (Lovegrove, Martin, & Slaghuis, 1986). While this position is not without some strong criticism (Hulme, 1988), the evidence of early visual processing differences between SRD and normal readers (to be reviewed in Section 1.3.4) merits further investigation of this position. Before presenting a review of the visual deficit hypothesis, an examination of the phonological deficit hypothesis is conducted.

1.2 Phonological Deficit Hypothesis

Over the years there has been a large amount of research compiled on all facets of reading disabilities. The following section will review a number of general letter studies before examining the studies by the most predominant researchers of the phonological deficit hypothesis. Studies have varied from Field and Field (1974) who used four letter words against a confusing background, to Pavlidis (1981) who examined eye-tracking differences between SRD and normal readers. Another interesting area of study in the reading disability area is reversal errors.

Reversals are a well known phenomena of SRD. They include static reversals (the confusion of mirror image letters such as ‘b’ and ‘d’) and kinetic reversals (some and all letters within a word such as ‘was’ and ‘saw’). While these errors occur normally when a child learns to read, SRD are distinguished due to the persistence and frequency of these errors (Eisenberg, 1966, cited in Willows, Kruk, & Corcos, 1993). Bigsby (1985) investigated these reversal errors by comparing SRD with Chronological-age matched controls and Reading-age matched controls. The researcher found that SRD made three times as many errors as the Chronological-age matched controls in one of the four same different letter tasks used. Other reading studies conducted have focused on distinct areas such as Allegretti and Puglisi's study (1986), which endeavoured to investigate at which level SRD may have a deficit.

Allegretti and Puglisi (1986) conducted a study with a SRD and a normal reading group using a letter-search task and found that SRD made significantly more errors than normal readers. Allegretti and Puglisi (1986) also found that SRD had a deficit when processing greater amounts of information compared to normal readers. This is known as the ‘increasing load hypothesis’. The researchers also examined if words were superior over non-words, but the results failed to support their hypothesis.

It is now well established from the plethora of research that SRD have deficits in phonological processing (Benton, 1975; Bradley & Bryant, 1983; Stanovich 1993; Vellutino, 1987). Vellutino and colleagues (Vellutino, 1987; Vellutino, Pruzek, Steger, & Meshoulam, 1973; Vellutino, Steger, De Setto, & Phillips, 1975; Vellutino, Steger, Kaman, & De Setto, 1975) support the findings of phonological-coding deficits by investigating visual perception skills of SRD, as compared to normal readers. These researchers found that SRD children are unable to phonemically segment, have an inadequate vocabulary development, and are unable to represent and access the sound of a word (which hinders remembering words). The researchers also suggested that SRD children have problems discriminating grammatical and syntactic differences among words and sentences, and have a dysfunction during the storage and retrieval of linguistic information (Vellutino, 1987). Furthermore, they claim that reversal errors (which might suggest a visual deficit) are a consequence rather than a basic cause of reading disability.

Vellutino (1987) states that SRD appears to be due to a complex linguistic deficiency and not a visual problem. This conclusion is drawn from two series of studies that found no visual differences between the groups. In the first series of studies, SRD children were asked to copy and recall orally words, geometric designs, scrambled letters and numbers after a brief visual presentation. Vellutino (1987) found that participants could read aloud the letters of the words in correct order even when they named the word incorrectly. The researchers expected poor and normal readers to have a comparable performance in the immediate visual recall (copying) of words except once the normal limits of visual short-term memory were reached. Additionally poor readers were expected to have an inferior performance in verbal identification (pronunciation) irrespective of length of the word.

Vellutino (1987) found that dyslexic readers can perceive letters and words accurately but they mislabel them (Vellutino, Harding, Phillips, & Steger, 1975; Vellutino, Smith, Steger, & Kaman, 1975; Vellutino, Steger, & Kandel, 1972). From these series of studies the SRD group performed better at visually recalling tachistoscopically presented three, four, five-letter words than in pronouncing these words. This indicated to the researchers a lack of verbal rather than visual information.

In the second series of studies there were three experiments (Vellutino, Harding, Phillips, & Steger, 1975; Vellutino, Pruzek, Steger, & Meshoulam, 1973; Vellutino, Steger, Kaman, & DeSetto, 1975) that asked children to reproduce words from an unfamiliar writing system. After a brief exposure to Hebrew words, SRD, normal readers and children learning Hebrew had to place the letters in the correct sequence and orientation. While SRD and controls performed the same, neither group performed as well as the children with exposure to Hebrew. Even with no meaning, the visual recall of symbols was the same for both groups. This result supports a linguistic rather than visual coding system. However Reddington and Cameron (1991) explain the results of the Hebrew studies by stating that the stimulus was too unfamiliar and difficult for both reading groups. Therefore the failure to find differences between the two groups may have been a floor effect.

Vellutino and his associates (Vellutino, 1977; 1979a; 1979b; Vellutino, Harding, Phillips, & Steger, 1975; Vellutino, Steger, Harding, & Phillips, 1975; Vellutino, Steger, & Kandel, 1972; Vellutino, Steger, Moyer, Harding, & Niles, 1977;

Vellutino, Steger, & Pruzek, 1973) have endeavoured to show that visual processing of SRD is no different from normal readers. Other researchers have also expressed methodological and statistical concerns with these studies (Fletcher & Satz, 1979a; 1979b; Rie & Rie, 1980; Singer, 1979). These studies were criticised for using relatively small sample sizes and questions have been raised about the interpretation of the data. Additionally, as Willows et al. (1993) state, the results of the first two experiments can be interpreted to support rather than refute a visual processing difference between the two groups. Willows, Kershner, and Corcos (1986, cited in Willows et al., 1993) modified Vellutino's experimental design and found early visual memory deficits.

Willows et al. (1993) attribute the difference in the findings as being due to the construct validity of the tasks used in Vellutino's series of experiments. They suggested that the tasks were confounded with a memory component. Willows et al. (1993) states that the main problem for visual processing research is eliminating the potential for linguistic confounds. They claim that while it may seem obvious to test SRD and normal readers with letter and words, it creates problems with possible higher-order processes such as verbal labelling, rehearsal and cognitive strategies (Willows, et al., 1993). Badcock and Lovegrove (1981) also state that the type of visual task used is crucial. Vellutino used isolated spatial arrays where other studies (Lovegrove & Brown, 1978; Lyle & Goyen, 1975; Stanley, 1975; Stanley & Hall, 1973) used short durations and/or successive presentations of stimuli.

While it seems intuitive to use actual words to examine any relationships with SRD children, as Reddington and Cameron (1991) state, studies which use letter or word recognition do not sufficiently address the nature of SRD deficits. With this interim conclusion, the thesis now moves to a discussion of visual processing in SRD.

1.3. Visual Deficit Hypothesis

The earliest visual study was conducted in 1790s when two typefaces were manipulated by spacing distance until it could no longer be read (Updile, 1928, cited in Willows et al., 1993). Studies began to examine eye movements in reading and found that the eyes move in saccades or jumps while reading. From the 1880s to the 1910s, perceptual studies of reading examined areas such as word recognition, eye movements, field of vision and perceptual span (Willows et al., 1993). This interest in abnormal visual functioning, which began in the early 19th Century, continues to receive research attention today. Orton proposed the earliest visual hypotheses (1925; 1937, cited in Hayduk, Bruck, & Cavanagh, 1996). Since these early beginnings, research has investigated deficits in short-term visual memory (Goyen & Lyle, 1973), in processing visual information sequentially (Bayliss & Liversey, 1985), in spatial localisation (Solman & May, 1990) and in visual analysis (Doehring, 1968).

From the 1970s there was a split in the research when researchers began moving away from examining difficulties in visual and visual-spatial processing (Hayduk et al., 1996) and attending to linguistic aspects, which largely remain the current centre of attention. However this may not be the whole story and interest in a visual deficit remains. While the present study cannot dispute the enormous amount of evidence that supports a causal relationship between phonological deficits and reading problems, it can highlight the influence of visual factors.

In order to examine the previous studies in this area of vision research, an understanding of the frameworks that surround this approach must first be addressed. The next section outlines the spatial-frequency analysis framework. Following this is a review of the evidence of two spatial-frequency sensitive pathways, and how this relates to reading. Lastly a review of the early and later visual processing studies is conducted in Sections 1.3.4 and 1.3.5.

1.3.1 Spatial-frequency Analysis

It is well documented that the visual system uses the information from the spatial-frequency of the visual image. Most neurones from the striate cortex are tuned to a particular spatial-frequency (Carlson, 1998). It is believed that early in visual processing the image is analysed in its spatial frequencies. Small objects and details are associated with high spatial-frequency and large objects, contours and global aspects of a stimulus are related to low spatial-frequency. This can be done in the laboratory using a method called Fourier analysis, which is a mathematical process where a scene is analysed into its component simple sine-waves (Bernstein, Roy, Skull, & Wickens, 1991). According to Fourier theory, any two-dimensional spatial pattern can be broken down into its spatial-frequency components (Breitmeyer & Ganz, 1976). Spatial-frequency gratings are measured by the number of cycles of grating included in 1 degree of visual angle (Lovegrove & Williams, 1993).

In human visual systems, it is suggested (Carlson, 1998) that magnocellular and parvocellular components of the lateral geniculate nuclei of the thalamus are respectively specialised for analysis of the information coming from low and high spatial-frequency.

1.3.2 Evidence of Two Distinct Pathways

The simplest model of visual information processing is for a single flow of information along a sequential process that moves from the receptor in the eye to the higher brain regions (Stillings, Weisler, Chase, Feinstein, Garfield, and Rissland, 1995). At each level, the system analyses the information available and then passes it on to the next level. In 1977, Hubel and Wiesel proposed a parallel hierarchical model of visual processing. From this model, Hubel and Wiesel (1977) state that there are two types of ganglion cells (magno and parvo), which have different spatial responses, temporal and chromatic properties. This concept of parallel processing has had a relatively long history in vision (Stone, 1983).

Initially information is collected by photoreceptors in each eye and transmitted away from the retina through to the ganglion cells (Matlin & Foley, 1982). From the retina, information is transferred from the photoreceptors to the bipolar cells and then to the ganglion layer. The fovea is saturated with cones, however with increasing distance from the fovea, the number of cones gradually decreases as does acuity, and the proportion of rods gradually increases (Bernstein et al., 1991). Information is processed in the superior colliculus, lateral geniculate nucleus as well as the visual cortex.

The small parvo cells and large magno cells are intermixed in the retina, and their axons project to distinct layers of the lateral geniculate nucleus. The parvo cells have small receptive fields that are sensitive to low contrast, responding slowly but giving a sustained response throughout detection of stimuli. They are predominantly in fovea vision and assist in colour vision (Lovegrove, 1993). Based on measures of flicker/motion and form/pattern detection thresholds, parvo cells prefer stationary stimuli, at high spatial frequencies and at low temporal frequencies. Magno cells are complementary, they have large receptive fields, and have a fast temporal response at the onset and offset of a stimulus (Lovegrove, 1993). Magno cells are more sensitive to low spatial frequencies, rapidly moving stimuli and high temporal frequencies. Additionally, magno cells predominate in peripheral vision and assist in night vision.

Parvo ganglion cells are dense in fovea and parafoveal regions. Magno ganglion cells have a fairly even distribution across the retina. The Magno pathway having larger receptive fields and being more sensitive to lower spatial-frequency, provides coarse spatial information that is important to identify the basic form and figure and ground relations (global information). The Parvo pathway has smaller receptive fields and is more sensitive to higher spatial-frequency and the perception of local aspects of stimuli. This is supported by psychophysical and physiological research that shows a visual system with parallel channels that are sensitive to particular spatial frequencies shown by different sine-wave grating patterns (Hughes, Layton, Baird, & Lester, 1984).

Magnocellular and parvocellular systems are closely analogous with transient and sustained systems. The discovery of X and Y ganglion cells in cat retina by Enroth-Cugell and Robson (1966) gave support for neuroscientists to determine the physiological and anatomical details of two human neural pathways (Breitmeyer, 1975; 1980; 1984; 1993). Kulikowski and Tolhurst (1973) and Tolhurst (1973) were among the first researchers to use the sustained/transient terminology, to describe pattern and motion sensitive pathways in vision.

The distinction between sustained and transient systems is now the basis of a well-studied theory in vision (Breitmeyer & Ganz, 1976; Tolhurst 1973). Anatomical (Mishkin, Ungerleider, & Macko, 1983), physiological (Zeki & Shipp, 1988), and psychophysical evidence (Breitmeyer, 1992; Breitmeyer & Ganz, 1976; Green, 1981; Kulikowski & Tolhurst, 1973) all support that visual information is transmitted from the retina in the eye to the visual cortex via these two separate specialised pathways (Lovegrove, 1993).

The thesis now turns to the evidence that there are two spatial-frequency pathways in the human visual system. From spatial-frequency theory, previous research has found evidence that two pathways (transient and sustained) process information while reading. The two pathways specialise in the processing of particular features of visual stimuli. These properties have been examined in a number of sine-wave gratings studies. How these two sub-systems relate to reading is the focus of the next section.

1.3.3 Transient and Sustained Sub-systems and Reading

It seems obvious that visual perception plays a vital role in making reading possible, as reading is primarily a visual act for visual readers. Reading is a process that requires the correct timing of eye movements, in order to be perceived in sequence from successive fixations. During reading, the eyes move in jumps rather than in smooth movements. These saccadic movements refer to the rapid movements from one fixation point to the next (Lovegrove & Pepper, 1994). These movements bring the fovea of the eye into position over the letters or words, which is termed the optimal viewing position (OVP) (Lovegrove & Pepper, 1994). Acuity within the fovea sharply declines at about 5 degrees either side, and this is called the parafovea (Pollatsek, 1993). During the fixation pause (between saccades), the letters or words are read (Lovegrove & Pepper, 1994).

Lovegrove (1993) states that both high and low spatial-frequency pathways are required in order to read. Deficits in either system could contribute to visual problems in reading. Additionally both systems may inhibit the other (Breitmeyer & Ganz, 1976; Singer & Bedworth, 1973) and a harmonious relationship is required. The transient pathway processes general information largely in peripheral vision using low spatial frequencies. Additionally, the transient pathway guides eye movements and integrates this information across fixations using high spatial frequencies. Conversely, the sustained pathway processes detailed information in central vision during fixations.

At the onset of each new eye movement, input from the last fixational pause is inhibited by the activity of the transient visual system (Breitmeyer, 1984). The sustained response may remain after the physical stimulus. If sustained activity generated in a preceding fixation persists into the succeeding one, it may interfere with processing (Lovegrove, 1993). The contents of each fixation may mask the next fixation, creating a timing disorder (forward masking by integration) that interferes with the rapid and smooth integration of visual information necessary for reading (Badcock & Lovegrove, 1981).

Breitmeyer and Ganz (1976) state that the faster-acting low-frequency channel that provides the general information from the periphery plays an important role in reading. The transient channel response commences after eye movements and lasts for a shorter duration than the sustained channel response. The sustained channel response occurs during the fixations and provides the details of what is being seen. Williams & Lovegrove (1992) state that the transient and sustained sub-systems have a role in reading.

A weak or sluggish transient system may fail to inhibit sustained channel activity causing visual persistence to last longer (Hogben et al., 1995). As a result, physical images of letters or words from one eye fixation may not disappear quickly enough to avoid interfering with the perception of images in the next fixation. The sluggish transient system of SRD children (Williams & LeCluyse, 1990) may make the text appear jumbled at least for the period of the last fixational pause. These effects have only begun to be investigated in controlled reading contexts however, problems of this sort with SRD have been reported by two researchers (Fisher, 1980; Jackson, 1976).

It was been suggested that the masking impairment may be reduced by slowing down the presentation of information, for this may lessen the difficulty in integrating information from successive fixations and assist in combining information from the two systems (Saint-John & White, 1988). Studies have used interventions such as coloured transparencies, Irlen lenses, and computer programs to improve transient activity by manipulating colour and acuity. However these attempts to artificially rectify the sequence have been equivocal. A number of these remediation techniques will be reviewed in Section 1.5.

The review in Section 1.3.4 outlines a difference in the functioning of the transient system in SRD children. These studies have found differences in transient system functioning, whereas the sustained system appears to be similar between the two groups. This anatomical defect in the transient pathway is thought to account for approximately 75% of SRD (Slaghuis & Lovegrove, 1985). In progressing with the review of previous vision research, a section on early visual processing follows.

1.3.4 Early Visual Processing

This section is intended as a review of the literature that asserts that SRD and normal readers differ in early visual processing. As stated previously, SRD is the umbrella term that encompasses reading disabilities that may have many causal factors. From Section 1.2 it can be seen that the predominant verbal/linguistic approach has much support (Stanovich, 1985; Vellutino, 1987). However the proposed study is concerned with the unclear role that a visual processing deficit could play in reading disabilities.

One of the main advocates for the visual deficit position is Lovegrove and his colleagues (Badcock & Lovegrove, 1981; Lovegrove 1993; Lovegrove & Brown, 1978; Lovegrove et al., 1986; Martin & Lovegrove, 1984) who have provided findings that suggested that SRD and normal readers differ in early visual processing. These researchers have attributed this difference to a low-level or early transient deficit. This basic letter recognition research is based on the spatial-frequency analysis and the transient and sustained frameworks discussed previously.

The following research makes the suggestion that a basic processing deficit in transient functioning could be related to SRD. As stated previously, processing information from one fixation may still be perceived after the eye has moved. Previous research suggested that the sensory memory of a stimulus appears to persist longer in SRD compared to normal readers (Lovegrove, 1993). A number of direct and indirect measures of visual persistence will be discussed in the following sections.

1.3.4.1 Interstimulus interval.

Previous researchers have consistently found longer interstimulus intervals (ISI) for SRD using two different types of gap detection tasks (Lovegrove, Billing, & Slaghuis, 1978; Lovegrove & Brown, 1978; O'Neill & Stanley, 1976; Stanley, 1975). Using a temporal integration task with an increasing ISI, Stanley and Hall (1973) found the separation threshold of SRD for two separate stimuli was significantly longer than that of normal readers. The temporal precedence was found regardless of whether the stimuli were blocked (same size) or randomised (varied in each block).

In a gap detection task, Di Lollo, Hanson, and McIntyre (1983) found significant differences between the means of the SRD and normal readers. Following the transient deficit model, it could be expected that the transient channel processes contrast preferentially at low spatial frequencies. The expected pattern of where SRD require a higher contrast than normal readers to detect low spatial-frequency gratings has been found (Badcock & Lovegrove, 1981). Hogben et al. (1995) suggested that there is a robust difference between SRD and normal readings using the gap detection task. This evidence suggested that the processing deficit may occur at the retinal level as opposed to later processing in the visual cortex (Slaghuis & Lovegrove, 1984; 1985).

Lovegrove, Heddle, and Slaghuis (1980) explain that visual persistence may differ due to a general developmental lag. They found that with three age groups (7,10,13), visual information store (VIS) duration decreases with age and with increasing spatial frequencies. Greater visible persistence was found in low spatial frequencies for SRD readers as compared to normal readers. The reverse results were found for high spatial frequencies. The increase in persistence with increasing spatial-frequency is interpreted as reducing the degree of inhibition of sustained to transient activity. The greater duration of persistence at low spatial frequencies for disabled readers can be understood as a lesser degree of transient on sustained inhibition in their visual systems.

Previous research has found that visual deficit decreases with age (Badcock & Lovegrove, 1981; Lovegrove & Brown, 1978) and that low-level deficits are found for the age range 6 to 8 years. However Slaghuis, Lovegrove, and Davidson (1993) state that the difference may remain in low-level visual processing in late adolescence (Slaghuis, Lovegrove, & Freestun, 1992) and in adults also (Winters, Patterson, & Shontz, 1989). Ongoing research in this area may be able to suggest the age at which some children are first taught to read.

1.3.4.2 ***Contrast sensitivity.***

Another measure that has found a difference between the two groups is contrast sensitivity. Contrast sensitivity is the smallest amount of contrast required to perceive a grating pattern (Williams & Lovegrove, 1992). A number of researchers have found that SRD are not as sensitive as controls at low spatial frequencies but are more sensitive to high spatial frequencies (Evans, et al., 1994; Lovegrove, 1993; Lovegrove, Bowling, Badcock, & Blackwood, 1980; Lovegrove, Martin, Bowling, Blackwood, Badcock, and Paxton, 1982; Martin & Lovegrove, 1984). However Lovegrove et al. (1980) did not find contrast sensitivity differences at higher spatial frequencies in one experiment.

Stanovich (1986) suggested that poor readers experience what he called the "Matthew Effect" where initial processing difficulty caused the reader to fall further behind. The question remains, does the transient deficit exist before children learn to read or is it produced during delayed reading acquisition? Williams and Lovegrove (1992) state a corollary question is whether subsequent reading performance can be predicted on the basis of visual measure. To examine this question, Lovegrove, Bowling, Slaghuis, Geeves, and Nelson (1986) used a contrast sensitivity measure on pre-readers. Contrast sensitivity was found to be a significant predictor of reading ability, suggesting that transient deficits exist before the reading process commences and therefore are not the result of a reading disability.

1.3.4.3 Uniform field flickering.

The third technique, which is a direct measure of any differences, is the uniform field flicker (UFF) masking. If the transient deficit hypothesis is correct, masking by UFF should minimise the difference between the two groups on contrast sensitivity or visual persistence studies. Slaghuis and Lovegrove (1984), Lovegrove et al. (1980) and Martin and Lovegrove (1987) found that this task reduces the difference between the two groups and this provides strong support for a slower and or weaker transient system.

Adding a 6 Hz UFF removes the difference as the SRD child then has too little transient on sustained inhibition to be affected by flicker masking, and normal readers reduce their magno activity to produce similar results to the SRD without the flicker mask. The transient deficit model explains why they are slower at contrast sensitivity, but only at lower spatial frequencies (where transient is dominant). This is why UFF (which reduces transient activity) has a differential effect on both groups at lower spatial frequencies.

1.3.4.4 Backward masking.

Another technique widely used in this research area is backward masking where one stimulus is followed so closely to another that the second interferes with the processing of the first. The results from this paradigm suggested that SRD process visual information more slowly then normal readers, and the time interval between target and mask is longer (Di Lollo et al., 1983; Lovegrove & Brown, 1978; Mazer, McIntyre, Murray, Till, & Blackwell, 1983; O'Neill & Stanley, 1976; Stanley & Hall, 1973) in SRD. The last research technique to be discussed, that has been used to determine if there are any processing differences between the two groups, is stimuli blurring.

1.3.4.5 Blurring.

It would be expected that a clear presentation of stimuli should produce a better performance than blurred stimuli. Williams and Lovegrove (1992) blurred presentations by using frosted acetate to remove the high spatial frequencies and found that SRD and controls had more similar performances. Lovegrove, Lehmkuhle, Baro, and Garzia (1991) also used a blurring UFF task to manipulate the global precedence effect across the groups. Global precedence will be more fully discussed in Section 2.1.1. In the practical sense global precedence is defined as the faster or earlier processing of the global level rather than the local level of a stimulus.

As discussed previously, the transient pathway is sensitive to low spatial-frequency and tends to process visual information faster than the sustained which is sensitive to high spatial-frequency (Breitmeyer, 1975). This supports the connection between a low spatial-frequency channel mechanism and global precedence. The global aspect of stimuli is processed by low spatial-frequency channels (Lovegrove et al., 1991; Shulman, Sullivan, Gish, & Sakoda, 1986) and since the global is generally processed faster than the local letter, this leads to the hypothesis that the global precedence effect should be absent when the low spatial frequencies are removed.

Lovegrove et al. (1991) found that the UFF increased RT to global features and decreased RT to local features. Blurring had little affect on global RT but increased RT to local stimuli. This supports global precedence being partially the result of low-level visual mechanisms and is consistent with the idea that slower high spatial-frequency are disinhibited when fast low spatial-frequency are masked by the UFF.

Williams, Brannan, and Lartigue (1987) found that blurring the stimulus led to a dramatic improvement in performance for poor readers and did not affect good readers. Hogben, Pratt, Dedman, and Clark (1996) replicated the study of Williams et al (1987) as closely as possible, while claiming to have made methodological improvements. Hogben et al. (1996) state that the blurring of the image may reduce the sustained response to one fixation, which makes it easier for the weak transient system of SRD to inhibit its persistence. The sustained response to the succeeding fixation would be reduced making it less visible. The net effect would be loss of detail in fixations, making any overall gain unlikely for SRD. While these results are not consistent with Williams et al. (1987), they do not deny the explanation of reading disability based on the transient deficit theory (Hogben et al., 1996).

While differences have been found between SRD and normal readers in the transient system, the sustained system is thought to function normally in both groups. Lovegrove et al. (1986) found spatial tuning (which is controlled by the sustained system) to be similar in SRD and controls. Additionally, better performances have been found on sustained tasks such as high spatial-frequency sensitivity, visual acuity and oblique effect, for SRD which support the view that there is no difference in sustained functioning (Lovegrove et al., 1986).

1.3.4.6 *Evoked potential.*

Another line of evidence from electrophysiological and anatomical findings is that visual evoked potentials (VEP) have been found to be different in the two groups when viewing sinusoidal grating stimuli (Kubova, Kuba, Peregrin, & Novakova, 1995; May, Lovegrove, Martin, & Nelson, 1991; Mecacci, Sechi, & Levi, 1983). Livingstone, Rosen, Drislane, and Galaburba (1991) found abnormally long VEPs to low contrast, low spatial-frequency stimuli. However the findings in this area are not consistent and need further research. Additionally, Eden, VanMeter, Rumsey, Maisog, Woods, and Zeffiro (1996) found support for the transient deficit in an fMRI study.

1.3.4.7 *Anatomical evidence.*

Livingstone et al. (1991) also found from autopsy information that the lateral geniculate nucleus in SRD had smaller cell sizes, were more varied and disorganised in the magnocellular layers but not in the paravocellular layers. The smaller axon width causes a reduced capacity to process rapidly presented stimuli. From post mortem studies, SRD and controls appear to have a similar sustained pathway

(Breitmeyer, 1993; Lovegrove, 1993). Galaburda and Livingstone (1993) found less myelination in the cells of SRD, causing difficulty in processing rapidly presented auditory stimuli. All the researchers in this area express caution from their preliminary findings for they often are based on few subjects.

To summarise Section 1.3.4, psychophysical studies of phenomena such as visual persistence, flicker sensitivity, and blurring are suggestive of the involvement of transient-channel deficit in SRD. These studies challenge the prevailing view of Vellutino (1987) that visual deficits do not exist in SRD. Most support has been found for low-level sensory processing deficit rather then a higher-level one. Lovegrove et al. (1986) explain some of the null results on visual tasks as being due to methodological flaws. They acknowledge that some researchers may indeed be correct with their null findings, however, others may be examining higher-order rather than lower-level deficits. Lovegrove (1993) acknowledges the precise nature of visual deficits is still unclear and further research is warranted.

While there are many advocates for the visual hypothesis, not all researchers agree. Hulme (1988) has outlined a number of criticisms concerning the visual deficit hypothesis. Lovegrove (1991) addressed in some detail five areas that Hulme (1988) stated were of concern and these will now be reviewed:

Hulme (1988) states the following:

1. Criticism: There is much evidence that SRD do not perform better with isolated words (where there is no possibility of superimposition).

Response: Lovegrove (1991) explains this criticism by highlighting that semantic and spatial/visual aspects are confounded in such tasks. Additionally it is unclear how the effects of both aspects interact. Lovegrove (1991) suggested that tasks should separate out semantic and spatial/visual context by presenting one word at a time to limit eye movements and using only foveal information rather than both foveal and peripheral. Additionally Lovegrove (1991) states that this deficit is not the only difficulty that SRD face and he agrees that the problem with individual words is that they do not reflect phonemic difficulties.

2. *Criticism: Common errors made by SRD reflect phonological recoding difficulties.*
Response: Lovegrove (1991) states that more research on the relationship between visual and phonological errors is needed.

3. *Criticism: Evidence suggests no differences in SRD visual processing.*
Reponse: Lovegrove (1991) suggested that much of this statement is from Vellutino's research alone and these studies face strong criticism. He also suggested that this view needs to be reconsidered in light of other research in the spatial-frequency framework.

4. *Criticism: The tasks used lack face validity.*
Response: Lovegrove (1991) acknowledges that the tasks lack face validity. However he questions how important this is. He claims that the studies have a theoretical link to reading rather than mimicking the reading process and that closer approximations are difficult to interpret and are open to criticism of being too correlated with reading.

5. *Criticism: There has been no evaluation of the benefits of any remediation program resulting from this research.*
Response: Lovegrove (1991) refers to studies by Williams who manipulated the transient and sustained system by using spatial filtering in high level tasks.

1.3.5 Later Visual Processing

A major research approach in examining if visual processing deficits are involved in reading disabilities is the Disabled-Normal reader comparison. The evidence found is mixed as to whether SRD have greater difficulty in visual processing as compared to their normal reading counterparts. This section outlines a number of studies which examined later levels of visual processing and higher cognitive processing and found no difference between SRD and normal readers, whereas others have found conflicting results when focusing on early visual processing (Di Lollo, et al., 1983; Lovegrove, et al., 1986). Willows et al. (1993) suggested that the difference in the findings may be due to the stage of processing being investigated. While the visual processing activity varies between the studies the research can be divided by considering the level of visual processing assessed. As mentioned previously information starts to be processed as soon as information reaches the eye (early visual processing) and proceeds from the retina to the visual cortex and to the associated areas of the brain (later visual processing).

The studies discussed in Section 1.3.4 all examine early visual processing. While this is of greater importance to the present study, a few of the key studies from later visual processing will now be outlined as they reinforce the notion that SRD and normal readers have differences in this area. Williams and a number of other researchers have conducted studies in this area, which will now be addressed.

Williams and LeCluyse (1990) state that both earlier and later visual processing research has found a difference between the SRD and normal readers.

Williams and her Colleagues (Williams, Breitmeyer, Lovegrove, & Gutierrez 1991; Williams & LeCluyse, 1990; Williams, LeCluyse, & Bologna, 1990) found results that support the idea that there is a difference between higher-order perceptual processing differences of SRD and normal readers. The four areas that have been examined include- visual recognition memory, reproduction from visual memory, visual paired-associate learning and serial learning of visual designs.

Lyle and Goyen (1968) and Goyen and Lyle (1971) found poor readers performed worse than normal readers on tachistoscopic recognition tasks using short spans of attention. Goyen and Lyle (1973) went on to ask poor and normal readers to judge whether pairs of geometric shapes were the same or different in order to investigate any short-term memory differences. The researchers found that SRD made significantly more errors than normal readers in those tasks. Willows, Corcos, and Kershner's (1993) study found similar results to those of Lyle and Goyen. They examined visual recognition memory for unfamiliar visual symbols, using letters from the Hebrew alphabet in a same-different paradigm. The SRD were less accurate and slower in visual recognition.

In order to be able to read and write, children must be able to remember visual information (Willows et al., 1993). Vellutino has carried out well known studies of visual memory using Hebrew letters. These studies were reviewed in Section 1.2. Vellutino took another line when comparing SRD and normal readers' ability to associate pairs of unfamiliar designs with each other and found no difference between SRD and normal readers to associate visual designs (Vellutino, Harding, Phillips, &

Steger, 1975; Vellutino, Steger, & Pruzek, 1973). Participants were in an older age range (9 ½ to 12 ½ years) and the task had a relatively long stimulus presentation.

While the research from later visual processing has largely found no difference between the SRD and normal readers, the research from early visual processing has been more consistent in finding a difference. As stated at the beginning of this section, it is early visual processing that is of greater importance to the current study. From the research reviewed above it is appears unlikely that there is a difference in visual memory of older children, however, there is a possibility of a developmental lag in visual memory for younger children. Willows et al. (1993) suggested further carefully conducted research is required in order to clarify the retention between later visual processes and reading disability, particularly in children below 8 years of age.

Studies on visual information store (VIS), duration rate of transfer to STM (Lovegrove & Brown, 1978; Stanley & Hall, 1973) and visual short-term memory (VSTM) (Stanley & Hall, 1973) indicate that SRD process slower and have less capacity than normal readers. Breitmeyer (1980) found that SRD had longer VIS durations than controls and that the difference between the groups decreases with increasing age.

Examining the fourth task, Brannan and Williams (1988) also found in a later study that SRD need more time to identify the order of two simple words. Brannan and Williams (1987) provide evidence of a sluggish transient system as SRD were slower than normal readers when stimuli were presented less than 59 milliseconds before. This leads to the notion of processing differences between the two groups in early visual processing. While criticisms of the transient model remain, further research should continue to explore the transient-deficit model using other experimental paradigms. The possibility that a visual processing deficit underlies and links with phonological impairments in SRD and the possible developmental course of SRD is explored in the next section.

1.4 An Integrated Approach

From the detailed discussion in Sections 1.2 and 1.3 it appears that both approaches agree that there is a specific processing difficulty, however, they see the basis of the problem quite differently. A model based on a combination the models of the deficit in phonological awareness and transient deficit hypothesis may begin to explain the different findings in this reading research area (Lovegrove, 1996). Eden, Stein, and Wood (1993) investigated visual processing and phonological recoding and concluded that there was a direct link between transient system processing and SRD.

In keeping with the suggestion that phonological coding may be linked to the transient system deficit, Lovegrove (1996) proposed that to provide a complete model of dyslexia, both approaches must be integrated, by looking at both the reading of single words and of continuous text. Predominantly previous experiments have utilised words and non-words with single fixations. This does not allow for increased errors during the reading of continuous text.

According to the transient deficit theory, SRD should make more errors when reading continuous text than isolated words due to the failure to integrate fixations. Hill and Lovegrove (1992) examined this by varying the mode of visual presentation while controlling the rate of presentation and semantic context. The results supported that SRD have difficulty in integrating peripheral and central information, but did not support the superimposition of successive fixations. Lovegrove (1996) explains this result in terms of a combination of the two major approaches.

Lovegrove, McNicol, Martin, Mackenzie, and Pepper (1988) examined any relationship between transient processing, phonological awareness, and recoding and working memory in SRD and cohorts. They compared flicker sensitivity, segment comparison, nonsense words and sentence verification. These measures were analysed with a factor analysis that showed a relationship between phonological recoding and loaded on transient processing without revealing the precise relationship. Lovegrove et al. (1988) state it is premature to reject the possibility of a link between visual and phonological processes in reading.

Rayner (1993) proposes-

> "Most studies are based on the unitary explanation assumption. There is a problem with the unitary explanation because many researchers have (a) assumed all dyslexics are alike in their symptoms and difficulties, (b) assumed that because dyslexia is a unitary syndrome, it must have a single cause and, (c) developed a theory to explain the one and only cause of dyslexia". (p. 477)

Rayner (1993) states there are many reasons why a child may experience reading difficulty. Rayner uses the analogy of being sick-

> "People can be sick for many reasons and they have different symptoms of being ill. There are also many different underlying causes of sickness. Obviously, some people are more seriously ill than others. I suspect that similar points can be made about dyslexics." (p. 478)

It has been raised that the results found from low-level visual research may not be representative if a certain type of dyslexic is being selected. Lovegrove (1996) states that the amount of evidence found makes this suggestion unlikely. Lovegrove (1996) conducted a multiple regression of the transient pathway deficit studies. He found that inconsistent results might be explained by using different tasks, subject selection and severity of reading disability. Lovegrove (1993) explains that studies in this area may have contradictory findings because they may be measuring the sustained (rather than the transient system) or they are measuring transient and sustained interactions (for the two systems are interdependent) or a failure to distinguish between the measurement of temporal and pattern-formation processes. Therefore controlled studies need to continue to confirm any deficit in the transient system.

Visual deficit studies have been criticised on the grounds of construct validation. The tasks may not appear to measure what they claim. Rie and Rie (1980) suggested that the fact that SRD differ on so many tasks, reflects an impurity in the experimental measures a single construct are probably sensitive to several other constructs. This problem was highlighted in the Vellutino studies. Rie and Rie (1980) state that the problem with the research in this area lies in defining the target groups. They claim the research needs to be simplified to the basic variables of age, intelligence, reading level, and the relevant tests used.

Hogben (1996) also suggested that the selection process used may account for conflicting results in psychophysics. Studies using school students seem to show deficits in transient function, whereas studies from reading clinics or special schools are unlikely to find a difference. Researchers are guided by Stanley and Hall's (1973) criteria for selecting children with SRD, however, it is suggested that studies may be drawing from different populations. Hogben (1996) states that it is important that the characteristics of participants be fully reported in order to aid future research comparisons and assist in homogenising samples to increase the likelihood of getting an experimental effect.

Hughes et al. (1984) raise the point that most studies have used compound stimuli and that the phenomenon should be explored using a wider range of stimuli. While the visual deficit hypothesis has been criticised for using stimuli that are not similar enough to the reading process, researchers in this area have also had their results criticised due to the restricted age range of participants. Predominantly the transient deficit channel studies have had participants with ages ranging from 8 to 14 years. This raises the question of whether these results will generalise to other ages. Additionally, in order to examine the effect of age, research must continue to assess developmental factors over time, as the effect of this remains unclear.

Rack (1995) states that while studies support phonological deficits, he urges future researchers to examine other methodologies to account for SRD. In conclusion it appears there is not enough research to support a causal unitary deficit theory for either position. Stein (1991) found support for both phonological and visual deficits and therefore concluded that SRD may experience both deficits. It appears that the challenge for future investigators is to unfold the interaction or relationship between linguistic and visual factors that may cause SRD by conducting longitudinal studies (Willows et al., 1993). This thesis now moves to the next section, which is an examination of the literature surrounding remediation and interventions.

1.5 Interventions

The purpose of researching SRD is to provide assistance to those who experience reading difficulties. In this section, the various remediation techniques used to rectify the deficits are described. Understanding the cause of SRD is important in both practical and theoretical terms and is of great importance to SRD children, their parents and teachers. Knowledge of SRD may facilitate early detection of potential differences and possibly screen for those difficulties in the early stages or may even prevent SRD from occurring. A greater understanding of the underlying cause of SRD is important in devising appropriate remediation. Since the predominant approach to reading disabilities is phonemically based, so are its treatments. Various remediation programs have been developed using principles of phonological awareness, however, if future research reveals that dyslexia has a visual deficit sub-type, different intervention strategies may be more effective with these SRD children. Therefore visual deficit sub-type studies must be conducted to confirm this. Rayner

(1993) stated that not all remediation techniques would assist all SRD children and the remediation needs to be tailored to the individual needs. He claimed it makes research and remediation more challenging but hopefully also more effective for a range of SRD sub-types (Rayner, 1993).

Remediation programs with an emphasis on visual processing have included reading using tinted glasses, reading with one eye covered, and changing the contrast of the letters and the paper background. Irlen lenses are used to assist people with sensitivity to light, which was originally termed scotopic sensitivity, which suggested that the rod receptors are too sensitive (Saint-John & White, 1988). Wilkins (1993) suggested that there is little scientific evidence to justify its use. While optometrists have been prescribing tinted glasses for people with photophobia for a long time, it has been recently highly publicised that these glasses also provide benefits for SRD children. Wilkins and Neary (1991) examined the effectiveness of the lenses with SRD and found that most of the participants reported only a modest increase in speed in visual search tasks. The popularity of the lenses could be due to a placebo effect with both the children and their parents having high expectations.

Irlen (1983 cited in Lehmkuhle, 1993) claims that the coloured overlays, tinted non-optical glasses, defocusing, and luminance reduction can facilitate reading by restoring the normal order of information flow from the two pathways that is required to read. When SRD read their sluggish transient system may fail to inhibit sustained channel activity and this may cause disturbing perceptual instabilities making it difficult to read. The text could appear superimposed or jumbled due to the physical images of letters or words from one eye fixation not disappearing quickly enough to avoid interfering with the perception of images in the next fixation (Williams & LeCluyse, 1990).

The use of filters or overlays may reduce and slow the activity of the sustained pathway by restricting the range of wavelengths reflected by the text. Slowing the sustained response may restore the correct sequence of the two pathways and this would assist reading by removing allowing a smooth integration of visual information as opposed to seeing jumbled letters that overlap. The Parvo pathway (sustained sub-system) is more selective in wavelengths so fewer wavelengths in the filtered text reduces its response. The Magno pathway response (transient sub-system) is less selective about the wavelength and would be less affected by the overlays or lenses (Lehmkuhle, 1993).

A number of researchers have examined the role of light wavelengths on visual processing. Metacontrast is weaker for stimuli presented on red rather than white or green backgrounds (Breitmeyer, May, & Heller, 1991; Breitmeyer & Williams, 1990). Metacontrast enhanced when stimuli were flashed on blue as compared to white or green backgrounds and this illustrates that long wavelength blue backgrounds suppress transient activity. Breitmeyer et al. (1991) stated that theoretically it would not be expected that red backgrounds would decrease the strength and blue backgrounds would increase the strength of saccadic suppression. It is thought that blue overlays or glasses may normalise the temporal relation between the two systems increasing the strength of saccadic suppression. This would alleviate the transient deficit and may lead to better reading performance. The theory is that red overlays and glasses would decrease an already deficient transient activity and lead to a lower performance.

This theory was tested by Williams, LeCluyse, and Faucheux (1992) who found that using red overlays decreased reading rate and comprehension in SRD children, as compared to reading without overlays. When the participants read with blue overlays the reading rate and comprehension results increased significantly. Breitmeyer (1993) states that the findings in this area need to be replicated before the results can be used as a remediation technique.

The challenge remains to translate existing research into appropriate education practices that remain grounded in theory but have enough flexibility to incorporate further research findings. There is widespread disagreement concerning educational approaches and research into what should be the focus of remediation. It appears that research into the treatment of SRD using the visual processing approach has not been supported by the research in that area. It also appears that programs need to adapt to fit the child's individual learning needs in order to be effective (Taylor, Harris, & Praeson, 1988).

In continuation of this thesis, the rationale of the current study will be outlined.

1.6 The Present Study- Participants and Rationale

This study's design has three groups (SRD, Chronological age-matched, and Reading age-matched). The Chronological age-matched group was included in the study's design in order to enable a base line comparison between visual processing of SRD and individuals who have a normal reading age. The Reading age-matched group was included to compare the SRD children to younger children with the same reading level on the same experimental tasks. The Reading age-matched group read at the same level as the SRD group, therefore it could be suggested that their transient system would be of equal status to the SRD group. It is important to include the Reading age-matched group in order to examine if any differences in visual processing occur.

Any performance differences between SRD and Reading age-matched group then may be explained by a deficit or due to a developmental difference, or any other factors (Felton & Wood, 1992). The use of two control groups is common practice in this area of vision research. The study's design is in keeping with previous research. The SRD group was compared to the Chronological age-matched group in order to compare the results of normal readers in the same age group, whereas the SRD group was compared to the Reading age-matched group in order to determine if there were any differences in the experimental task between children at the same reading level but a younger age.

Whilst much controversy surrounds definitions, comparisons between studies require some consistency in SRD criteria. In the tradition of previous research in this area, the SRD readers were identified by the following criteria, a procedure which is similar to that developed by Stanley and Hall (1973):

(1) A reading lag of at least 2 years below that expected for their age as measured by the Neale Analysis of Reading Ability-Revised (NARA-R).

(2) Average intelligence as measured by the Weschler Intelligence Children's Scale-Revised (WISC-R).

(3) No gross behavioural or emotional problems or organic disorders.

(4) Normal visual acuity.

The overall aim of this study was to examine whether SRD visual processing differs from the normal reading groups in processing of global and local levels of visual information, with changes in stimulus eccentricity and size, and when processing incongruent information. The aim of Experiment 1 will be to examine if there is any difference between SRD and normal readers in processing whole (global) in comparison to parts (local) of a stimulus. On the basis of the transient deficit hypothesis, it is expected that SRD will have difficulty in processing global information for this is where low spatial-frequency is associated. In reference to the transient deficit hypothesis, it is hypothesised that SRD will have a problem in processing the global level fast enough to preceed the processing of the local level. Consequently, it is possible that the SRD group may process local information faster than global information.

Following the global precedence hypothesis, it is expected that SRD will have problems in processing peripheral in comparison to central information, because peripheral vision is suggested to be associated with the transient sub-system. Experiment 2 is designed to examine peripheral vision of SRD observers. It is expected that processing of information at the centre of the visual field will be the same in the SRD and the Chronological age-matched group but processing of information in the peripheral visual field of the SRD group will be much slower than the Chronological age-matched group. There is no expected difference between the two groups when processing information at the centre of the visual field because the functioning of the sustained sub-system is associated with central vision and the sustained sub-system is thought to be functioning normally in both groups. The Reading age-matched group will be slower than both the other two groups in processing information from central vision due to developmental factors but they may be better than the SRD group in peripheral vision.

Consistent with previous research such as Carrasco, Evert, Chang, and Katz (1995) it is expected that the RT for all three groups will increase as the stimuli are presented further from the fovea. In Experiment 2, it could be expected that SRD may experience performance difficulties when stimuli are presented further from the fovea due to the involvement of the transient sub-system. This is because sustained activity is the strongest in the fovea and decreases with eccentricity, whereas the opposite trend occurs for transient activity (Breitmeyer & Valberg, 1979). It is expected that SRD may take longer to process information during parafoveal vision (global information). From Experiment 2 the results are expected to show that as eccentricity increases, RT will also increase for all three groups. The Chronological-age matched group will be faster than the SRD, while the SRD will have a similar performance to

Reading age-matched group.

A small line drawing is suggested to be associated with high spatial-frequency and a large line drawing is associated with low spatial-frequency (Antes & Mann, 1984). If small stimuli are associated with high spatial-frequency and large stimuli with low spatial-frequency and if the transient sub-system is most sensitive to low spatial-frequency, SRD with their weak transient channel may experience difficulties when processing large stimuli. Following the transient deficit hypothesis, when compared to the Chronological age-matched group, the SRD group may be slower when processing larger stimuli. Experiment 3 was conducted in order to examine whether size has an effect on the temporal order of processing on any of the three groups. It is expected that RT will decrease as size increases, for the two control groups. However the trend is expected to be reversed for the SRD group. It is expected that the Reading age-matched group may be slower than both the Chronological age-matched group and the SRD group.

Incongruent information is suggested to have a detrimental effect on visual processing of SRD individuals (Pomerantz, 1983). The fourth experiment aims to further explore the global/local relationship by looking at whether the global or local level dominates when readers must attend to one level but other level is providing conflicting information. Experiment 4 explores the effect of task demands and attentional constraints on global precedence hypothesis developed by Navon (1977).

According to the literature on global precedence effect if global information is inconsistent with local information the global level will interfere with the processing of the local. The SRD group may not show any global interference/facilitation but may show local interference/facilitation because the global system in this group is affected. Therefore it is expected that the SRD group may experience interference from the processing of local information rather than global interference. For if the literature on global precedence effect is supported, then the global level is processed prior to the local level. The SRD group due to a weak transient deficit, is expected to have a different interference pattern compared to the two control groups.

Chapter 2 discusses Experiment 1, which uses the global precedence paradigm to examine the transient deficit hypothesis.

CHAPTER 2: EXPERIMENT 1 - GLOBAL AND LOCAL PROCESSING

2.1 Literature Review

The transient deficit hypothesis is based, in part, on the assumption that the transient channel is associated with processing wholes rather than parts. Perhaps that is why SRD children show a deficit in learning to read using the whole word method in contrast to the phonological method. On the basis of the previously proposed evidence of two visual pathways, it could be speculated that SRD may have difficulties in processing the whole (global level) in comparison to parts (local level).

The global precedence effect to be discussed in the next section has received much attention. The Gestalt approach to perception emphasises that objects are perceived as whole structures rather than separated isolated parts (Matlin & Foley, 1982). Structuralism postulates that patterns are recognised from the parts of the stimuli (bottom-up) and this leads to the whole pattern. There is an active debate between the two schools of thought that provide a dichotomy from holistic global, Gestalt-like processing to analytic, local structural processing (Kimchi, 1992). Hierarchical patterns have been used for over 20 years to examine perceptual relations between global and local processing (Kimchi, 1992). The following section focuses on the studies that have investigated the earlier processing of the global level over the local level.

2.1.1 Global Precedence Hypothesis

In particular, two studies will be examined in detail in this section. Although both investigated global precedence, using similar method and stimuli, they found different results (Kinchla & Wolfe, 1979; Navon & Norman, 1983).

Kinchla (1974) was the first to ask participants to identify either the global or local letter of a compound stimulus (see Figure 1). The compound stimulus used in all of these studies was advantageous due to the stimulus being easily independently manipulated as compared to more natural scenes. For example, the large letter 'H' is made up of small 'E's and neither level cues the other level. Additionally, the patterns are not hampered by natural laws of placement, and familiarity and complexity can be controlled (Kinchla & Wolfe, 1979). The levels are equally complex, recognisable and codeable without being predicted by the other (Amirkhiabani & Lovegrove, 1997). Other researchers have used various other stimuli. For example, Boer and Keuss (1982) used rectangles, and Pomerantz (1983) used triangles and arrows as stimuli to examine the global precedence effect. Additionally Antes and Mann (1984) used line drawings of natural scenes and found similar results to Kinchla and Wolfe (1979).

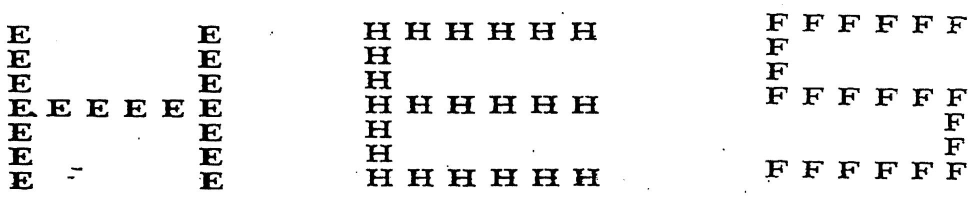


Figure 1. Local and global compound stimuli used by Kinchla (1974).

It was Navon (1977) who first questioned which level was initially perceived and he concluded that perceptual processing proceeds from global towards local details (global-to-local hypothesis). The 'whole' is considered to be the product of direct processing and not a product of recognising component parts (Amirkhiabani &

Lovegrove, 1997). Navon's (1977) results found that RT to the global level was faster than RT to the local level.

Subsequent to Navon's (1977) work was Kinchla and Wolfe's (1979) study that examined whether the angular size of an image determined the temporal order in which its components are perceived. Different sized stimuli were presented randomly in a block. The participants were uncertain about the size/eccentricity of each stimulus in the block. Kinchla and Wolfe (1979) found global advantage (global processed faster and fewer errors) when the stimuli were smaller than 6-9°, and conversely a local advantage when stimuli were larger than 6-9°. It should be noted that Navon (1977) used smaller stimuli while Kinchla and Wolfe (1979) used five visual angles that ranged from 4.8-22.1°.

Kinchla and Wolfe (1979) suggested that, rather than 'top-down' (higher levels first) or 'bottom-up' (lower-levels first), there is an intermediate level first with some level of both higher and lower being processed. The investigators termed this 'middle-out' processing where stimuli of an optimal size (6-9°) or spatial-frequency may receive processing priority and then the larger and smaller stimuli are processed. The researchers explain that this is due to larger stimuli falling in lower acuity regions of the retina and smaller stimuli being difficult even for the fovea.

Navon and Norman (1983) responded to Kinchla and Wolfe (1979) with a study that concluded that Kinchla and Wolfe (1979) confounded globality and eccentricity. The larger stimuli used by Kinchla & Wolfe (1979) would have global features falling onto the peripheral retina, while the local features would have fallen in the fovea area. Navon and Norman (1983) state that the confound of eccentricity could be rectified by using stimuli which have the eccentricity of its global and local levels equalised. To do this, Navon and Norman (1983) used the local letter 'C' to make up the global letter 'O' and local letter 'O' to make up the global letter 'C'. In these stimuli all the local elements were located along their perimeter (see Figure 2).

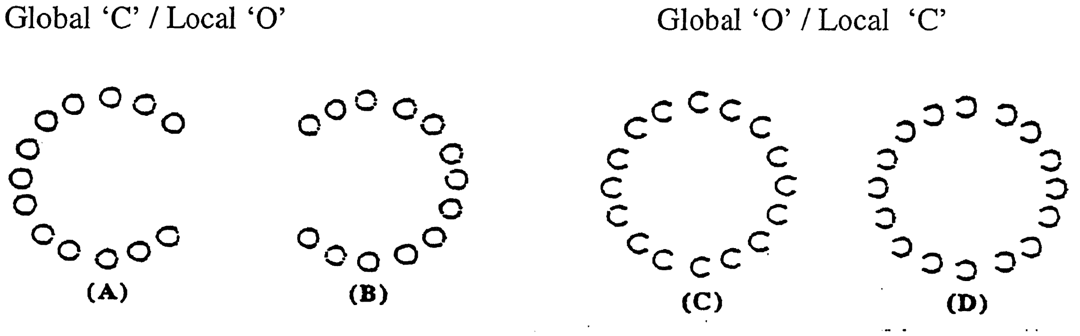


Figure 2. A sample of the compound stimuli used by Navon and Norman (1983).

In Experiment 1 of their 1983 study, Navon and Norman used stimuli of two sizes (small [2°] and large [17.25°]) that were exposed for 150 milliseconds. They had two separate blocks for these two sizes. Participants were certain about the size and the eccentricity of the stimuli being presented in each block. In other words, stimuli of small size were in one block, and stimuli of large size were in another block. The task was to respond to the opening direction of the letter 'C' either to the right of the left. The researchers concluded the difference in RT to the detection of the global and local levels would be due to the difference in their sizes for both small and large size of stimuli. The investigators concluded that the major variable affecting global precedence was size.

The studies conducted by Navon and Norman (1983) and Kinchla and Wolfe (1979) differ in a sense that in the former study the variable of eccentricity was controlled while in the later it was not. Kinchla and Wolfe (1979) used different eccentricities for global and local and used a divided attention task. The study had size/eccentricity uncertainty conditions as stimuli were in a mixed block. Navon and Norman (1983) used only two stimuli in a blocked condition where participants were certain of the size and eccentricity of the stimuli. Amirkhiabani and Lovegrove (1996) hypothesised that the difference in experimental conditions of two studies (size/eccentricity certainty versus size eccentricity uncertainty) could be the reason for the difference in the results of the two studies.

Amirkhiabani and Lovegrove (1996)continued the investigation by examining whether size and eccentricity uncertainty and certainty affects the global precedence effect in six experiments. They used a greater range of sizes than Navon and Norman (1983) with stimuli ranging from 0.5-16.3° and the global and local levels had equated eccentricities. Amirkhiabani and Lovegrove's (1996) study found that when the eccentricities of the global and local levels are equalised, global precedent is found regardless of if the participant was certain or uncertain of the size and eccentricity of the incoming stimuli. The researchers calm that the results indicate that size and eccentricity are the main determinants of the global precedence effect.

Many variables have been examined as a determinant of the global precedence effect and some studies have found the local level (rather than the global) can be favoured perceptually by manipulating stimulus variables such as the allocation of attention (Paquet & Merikle, 1988), low frequency content of stimuli (LaGasse, 1993; Lamb & Yund, 1993), and spatial-frequency filtering (Lovegrove et al., 1991; Martin & Lovegrove 1987). Exposure duration of stimuli (Luna, 1993; Paquet & Merikle, 1984), blurring stimuli (Williams & Lovegrove, 1992), and colour (Lovegrove & Pepper, 1994) has also been investigated.

2.2 Experiment Aims

As discussed in the previous chapter, some studies suggested that SRD individuals have a problem with their transient channel (Lovegrove, 1993). The transient visual sub-system is associated with the processing of global aspects of a stimulus in comparison to the sustained channel, which is associated with analysing wholes into parts and the processing of local information (Lovegrove, 1993). If all of these transient deficit premises are correct, it should be expected that SRD individuals will have difficulty in processing the global level in comparison to the local level of a visual stimulus.

In the current study, Experiment 1 aims to explore whether different patterns exist when comparing SRD to normal readers, in relation to the processing of wholes and parts. It is expected that SRD will perform similarly to Chronological age-matched controls in processing the local level, but will have significant deficit in processing the global level. This result is expected due to the faster processing of the global over the local being attributed to the faster processing of low spatial-frequency channels.

The experiment uses a global precedence paradigm with compound stimuli such as those used by Navon and Norman (1983) in order to study the transient deficit hypothesis. To trace any possible effect of global or local precedence across the retina, nine compound stimuli of different sizes were projected to nine different eccentricities. Similar to stimuli in Navon and Norman's study, the stimuli in this experiment had their local components located on their perimeters, in order to equalise the eccentricity of both the global and local levels.

The participants were uncertain of the size and eccentricity of the stimuli. While the experiment will be conducted in size/eccentricity uncertainty condition however, it is expected that on the basis of Amirkhiabani and Lovegrove's (1996) findings the results can be generalised to size/eccentricity certainty condition as well.

2.3 Method

2.3.1 ***Participants***

The study involved three groups, each containing 18 participants: SRD, Chronological age-matched normal readers, and Reading age-matched normal readers. The 54 participants involved were from two local primary schools. For inclusion in the study, the following criteria had to be met:

(1) Verbal and performance IQs above 90, as assessed by the Weschler Intelligence Scale for Children-Revised (Weschler, 1981).

(2) Be of English speaking Caucasian background and have had normal educational opportunities.

(3) Have no observable behavioural or emotional disturbances or known organic

problems. This information was obtained from teaching staff.

(4) Correct vision was determined by using a Snellen eye chart.

To identify the children for the SRD group, learning support teachers from both schools were asked to submit the names of children who had unexpected reading difficulties in view of their other abilities. The SRD group had to have a reading age at least 2 years below their expected ability level, as measured by the Neale Analysis of Reading Ability-Revised (Neale, 1995). The Chronological age-matched group was matched for age, gender, and intelligence and had to have an average to above average level of reading. The Reading age-matched controls were similarly matched and were normal readers who scored the same reading levels as the SRD group.

The Chronological age-matched group was included to have a base line comparison of reading age of SRD in comparison to normal readers. Reading age-matched group was utilised to have a base line comparison of the performance of individuals with reading ability similar to SRD in the experimental tasks. It could be claimed that because Reading age-matched control group read at the same level as the SRD group, then their transient system should be of equal status to that of the SRD group. Therefore it was important to utilise the Reading age-matched individuals as a control group. The use of two control groups (Chronological age-matched and Reading age-matched) is a common practice in this line of research.

The Neale Analysis of Reading Ability-Revised (Neale, 1995) was administered to obtain measures of students' reading rate, accuracy and comprehension of oral reading. Neale (1995) states that this test is one of the most widely used reading ability tests used in most western countries. This test has been standardised on an Australian population and consists of a series of graded passages that are to be read aloud. It is presented in a book, which is the symbol of literacy. The Neale Analysis of Reading Ability-Revised (1995) has been validated with rigorous study and is flexible in style for it has two alternative parallel forms. The same form was consistently used for all participants.

SRD children were included in the study if their mean score on the Neale Analysis of Reading Ability-Revised was at least 2 years behind their chronological age. Seven children were excluded because their reading scores were not sufficiently low. Each child selected was then carefully age matched (within 2 months) with a good reader. Good readers were included in the study if their mean reading age was at or above their chronological age. Participant details can be seen in Table 1.

2.3.2 Apparatus and Stimuli

Materials used in the pre-selection were: the Weschler Intelligence Scale for Children-Revised, the Neale Analysis of Reading Ability-Revised, a stopwatch, pencils, record forms, subject data forms and a Snellen acuity chart. The computer used for the stimulus presentation and data collection was a digital IBM compatible with a VGA monitor.

Table 1
Participants' Details- Age and Test scores for the all Groups

Groups	*Age in years*	*WISC-R Verbal IQ*	*WISC-R Perform. IQ*	*NARA- R*
Chronological				
Mean	*10.51*	*109*	*105.11*	*10.8 (+0.34)*
S.D	*0.88*	*5.81*	*7.86*	*0.8 (+0.01)*
Range	*9.58 – 12.17*	*95 – 119*	*93 – 120*	*9.5 – 12.5*
Female / Male	*12 – 6*			
Handedness (R- L)	*14 – 4*			
SRD				
Mean	*10.5*	*95.28*	*100.66*	*7.3 (-3.14)*
S.D	*0.87*	*5.21*	*8.42*	*0.4 (-0.37)*
Range	*9.5 – 12.25*	*82 – 103*	*86 – 114*	*6.5 – 8.25*
Female / Male	*12 – 6*			
Handedness (R- L)	*14 – 4*			
Reading Age				
Mean	*7.2*	*105.89*	*107.22*	*7.6 (+0.2)*
S.D	*0.47*	*8.21*	*10.78*	*1.1 (+0.09)*
Range	*6.75 – 8.42*	*92 – 118*	*90 – 121*	*6.34 – 8.42*
Female / Male	*12 – 6*			
Handedness (R- L)	*15 – 3*			
All Groups				
Mean	*9.41*	*103.39*	*104.33*	*+0.86*
S.D	*1.74*	*8.74*	*9.35*	*+0.04*
Range	*6.75 – 12.25*	*82 – 119*	*86 – 121*	
Female / Male	*36 – 18*			
Handedness (R- L)	*43 – 11*			

Note. Table 1 provides the average age of the participants in each of the three groups. Standard deviations and age ranges are stated. Each groups average scores for verbal and performance IQs are given as well as the NARA-A results. From the NARA-R results the average gap between the Chronological age and Reading age are shown (positive or negative). Handedness and female/male ratio are also given.

An adjustable steel and brass chin rest was used to stabilise the children's heads and was constructed by the Engineering Faculty at the University of Central Queensland. The chin rest was placed 60 centimetres from the computer screen. The stimuli were white on a black background. Stimulus viewing was binocular. The computer faced a wall and the room was semi-darkened with large black curtains. The contrast of the target was 90%. Test luminance was measured by a Tektronix J65261° narrow-angle luminance probe, and this was approximately 7.2 cd/m². All four vision experiments used the above apparatus and materials.

The task was to identify the direction of the opening of the 'C' at either the global level or the local level. The stimuli were large 'C's or reverse 'C's made up of small 'O's; or large 'O's made up of small 'C's or reverse 'C's (Figure 3).

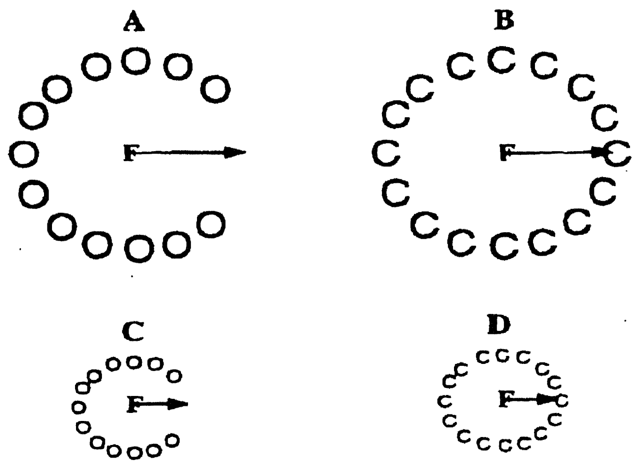


Figure 3. A sample of the compound stimuli used in Experiment 1.

Participants had their two index fingers resting on the two especially marked response keys on the keyboard of the computer. Amirkhiabani and Lovegrove (1996) and Boer and Keuss (1982) have found that participants find it difficult to respond to a right opening stimulus by pressing a key with the left finger and vice versa. Therefore, the response keys were not counterbalanced across the participants. Participants responded to four stimuli shown in Figure 3 of nine different sizes, which made up a total of 36 stimuli.

Stimuli were either large 'C's or reverse 'C' consisting of small 'O's or large 'O's consisting of small 'C's or reverse 'C's. There were 13 small 'O's in the perimeter of any of the large 'C's or reverse 'C's, and 16 small 'C's or reverse 'C's in the perimeter of the large 'O's. The visual angles of the global figures had one of the following nine sizes: 0.5°, 1.1°, 2.4°, 4.7°, 7.2°, 9.6°, 12°, 14.3° and 16.3°. The stimuli were circular figures that surrounded the fixation point, therefore the eccentricity of any of the global or local figures was equal to half of the size of the global configuration.

The size of any of the local figures was 1/8th of the global figure that they belonged to. In all sizes of both global and local stimuli, the size of the gap of 'C's or reversed 'C's was 72° out of its perimeter. Any of the four stimuli types in Figure 3 had an equal chance of being displayed in any of the nine sizes. The current study used the same stimuli type as Navon and Norman (1983) seen in Figure 2. As was mentioned above, to control the confound of eccentricity, all the local elements were located along their perimeter. This equalised the eccentricities of the global and local levels.

The size of the smallest stimuli (0.5°) was determined by the limitation of the computer software, as below that size it was not possible to draw a clearly visible stimulus. The size of the largest stimuli was 16.3°, as larger than that size would not fit onto the computer screen. The visual size of the stimuli could have been increased by asking the participants to sit closer to the monitor, however the participants may have found sitting closer than 60 centimetres to the computer screen to be disturbing. Between these minimum and maximum sizes, seven other sizes were employed to examine the sensitivity of the stimuli between these two limits. The selected sizes of the stimuli were somewhat arbitrary, but at the same time limited by the pixel capacity of the computer.

2.3.3 ***Procedure***

2.3.3.1 ***Selection testing.***

Before commencement, the consent of the Department of Education, the two schools, and parents of the children involved were obtained (see Appendix A for the Department of Education permission, and the parental consent form). Each child was tested individually in five separate sessions over a period of a few weeks. During the first session students were administered the Neale Analysis of Reading Ability-Revised and the Weschler Intelligence Scale for Children-Revised. The pre-selection results and the child's details were recorded on scoring sheets (Appendix B). These sheets compiled participant details such as grade, date of birth, Neale reading age, verbal and performance intelligence quotients and observations during testing.

If the participant met the necessary criteria in Neale Analysis of Reading Ability, then visual acuity was confirmed by the use of a Snellen acuity chart. Participants had to successfully read aloud a line from the chart at a distance of 3 metres. The time taken to administer the selection tests was approximately 1½ hours. This was followed by four separate experimental sessions that were counterbalanced.

2.3.3.2 ***Practice session.***

Each visual experimental session commenced with initial verbal instruction and tuition, and then a practice session. The aim of the practice session was to familiarise the participants with the requirements of the task. The practice session concluded once competence in the task was obtained. Participants were instructed to be both fast and accurate. The time taken to complete the practice session was an average of 8 minutes. Once familiarity with the computer and the experiment was gained, participants commenced the next stage of the experiment. The results of the practice session were not included in the analysis of data.

2.3.3.3 *Vision experiment.*

Participants were 60 centimetres from the computer screen. During the binocular task participants used a chin rest to minimise movement and to assist them in concentrating at the fixation point. The task was to identity the opening of the letter 'C' either at the global or local level. All four stimuli types were consistent, therefore unlike in Experiment 4, participants could only respond to one level as the stimuli. Participants responded by pressing two specially marked keys on the keyboard as quickly and as accurately as possible. They pressed the specially marked right key for stimuli that opened to the right, and conversely they were asked to press the marked left key if the stimuli opened to the left. The index fingers of the right and left hands remained resting on the assigned right and left marked keys.

To ensure attention and fixation on the middle of the screen, each presentation started with a display of the fixation point, which was a small filled circle in the middle of the screen for 2000 milliseconds. Once the fixation point was removed, the test stimulus was concurrently displayed with the fixation stimulus. The test stimulus and fixation stimulus exposure time was 100 milliseconds. The test stimulus was one of the figures displayed in Figure 3 and was in one of the abovementioned sizes. The fixation stimulus was an 'x 'or a '+'. On approximately 10% of responses participants were asked if the fixation stimulus was an 'x' or a '+' to ensure participants maintained concentration in the centre of the screen and to minimise possible eye movements and prevent fixation drift. The participants did not know at the end of each trial if they would be required to identify the fixation stimulus or not. They were interrupted randomly after the trial was completed. The fixation point (small filled circle) and fixation stimulus ('x' or '+') measured a visual angle of less than about 0.05°. Following the test stimulus was a blank screen that disappeared after a response or 2000 milliseconds time-out. Inaccurate answers produced auditory feedback. The next trial commenced either after the response or time-out, with the fixation point appearing on the screen.

The experiment consisted of six randomised experimental blocks providing a total of 45 trials per experimental block. In total there were 270 trials, with 135 trials in the global level and 135 trials in the local level. The three global and three local level blocks were counterbalanced, meaning the order was randomly chosen by the computer. The participants were uncertain of the size and eccentricity of the incoming stimuli. The size of the stimuli was varied within the blocks and whether the children had to respond to the global or local level was varied across the blocks. Response accuracy and RT to the test stimuli were recorded. The time taken to conduct Experiment 1 was an average of 30 minutes.

It took approximately 5 hours in total to test each child with the two pre-selection tests and the four vision experiments. Each participant completed the Weschler Intelligence Scale for Children-Revised and the Neale Analysis of Reading Ability-Revised and then had to pass the vision acuity chart. If the child met the selection criteria then the four vision experiments were conducted. The children were tested individually and each session was conducted on separate days and the four vision tests were counterbalanced.

2.4 Results and Discussion

Data from the practice session was not included in the RT analysis. Inaccurate responses on trials (5.3%) were omitted prior to RT analysis. The data entered into the analysis and graphs were derived from the participant's means.

The experimental design was a mixed 2 x 9 x 3 factorial design with Target level (global and local), Eccentricity (0.25°, 0.55°, 1.2°, 2.35°, 3.6°, 4.8°, 6°, 7.15° and 8.15°) as within-subject factors, and Reader group (SRD, Chronological age-matched and Reading age-matched) as the between-subjects independent variable. The analysis of variance (ANOVA) produced five statistically significant results, which are itemised below. Consistent with earlier findings, the global level ($\underline{M}=694.43$, $\underline{SD}=219.05$) was identified faster than the local level ($\underline{M}=751.28$, $\underline{SD}=237$), $F(1, 52) = 78.39$, $p<0.001$ for all three groups. The Reader group was significant $F(2, 52) = 12.08$, $p<0.001$ ($\underline{M}=722.15$, $\underline{SD}=330$). The extent of global advantage found also varied across eccentricity as indicated by a highly significant eccentricity main effect $F(8, 416) = 54.31$, $p<0.001$ ($\underline{M}=724.06$, $\underline{SD}=227.06$). A highly significant interaction between Target level and Eccentricity $F(8, 416) = 35.45$, $p<0.001$, may be an indication of the longer RT found at the local level for the smallest stimuli (0.25°) when projected to the smallest eccentricity. Additionally, the analysis shows that there was a significant interaction between Reader group and

Target level, *F(2, 52) = 3.30, p =0.045.*

The results for the Chronological age-matched group can be seen in Figure 4, which illustrates the mean response time for global (black bar) and local (dotted bar) levels. The results show that the global level was detected faster than the local level across the nine eccentricities, and this forms a quadratic ('U' shaped) function. It is noted that 0.25° was a particularly long RT for local information. There was a tendency to process both global and local information faster around eccentricity 2.35° and 3.6°.

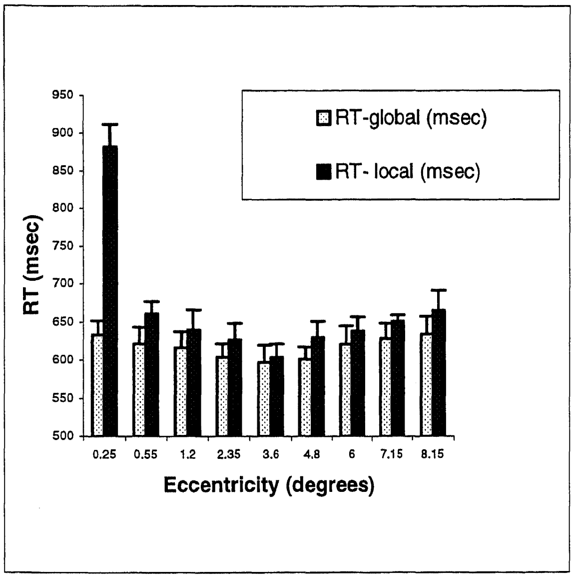


Figure 4. Mean RT as a function of target level and eccentricity for the Chronological age-matched group in Experiment 1.

Figure 5 illustrates a similar pattern for the SRD group. Repeatedly RT for 0.25° at the local level was unusually high possibly because the smallest size was too small to easily perceive. Figure 6 repeats the same pattern for the Reading age-matched group, however, the RT for this group were slower than the RT for

Chronological age-matched group across the nine eccentricities.

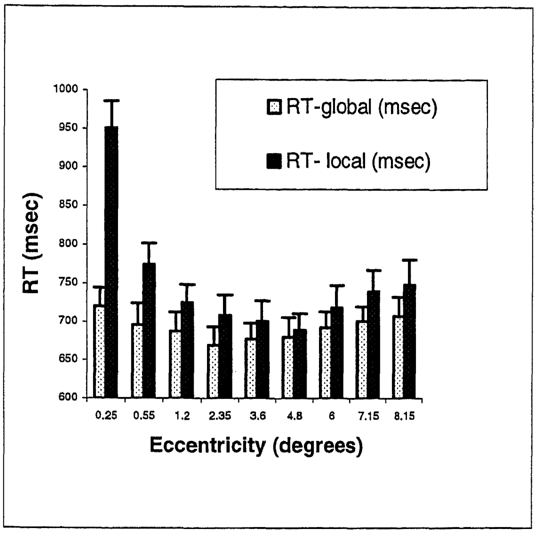


Figure 5. Mean RT as a function of target level and eccentricity for the SRD group in Experiment 1.

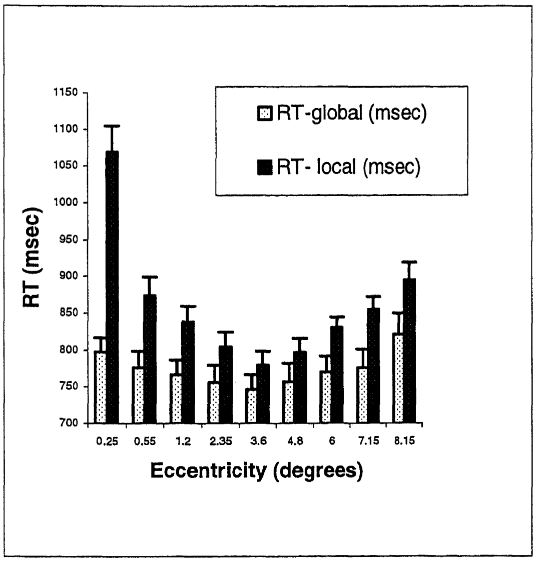


Figure 6. Mean RT as a function of target level and eccentricity for the Reading age-matched group in Experiment 1.

Similar to the other two groups, the Reading age-matched group detected the global level faster than the local level all across the retina. The pattern of RT to both global and local levels constituted a quadratic function. It was interesting to note that all three groups had a longer RT time to the smallest eccentricity (0.25°) which indicates this size tested the limits of visual processing. No doubt this influenced the interaction between target level and eccentricity discussed above.

Scheffe` Post Hoc comparisons were used to identify specific group differences. Figures 7 and 8 illustrate that the Chronological age-matched group had the fastest RT, and the SRD group was an average of 77 milliseconds *($p < 0.05$)* behind in processing the global and local level. The Reading age-matched group was the slowest, for they were 96 milliseconds *($p <0.05$)* behind the SRD group. The Chronological age-matched group was on average 183 milliseconds faster than the Reading age-matched group *($p <0.01$).* These time differences were maintained across the nine eccentricities. Shorter RT was found at the global level for all three groups.

Using the method of least squares to fit a general linear model indicated that patterns of RT to both global and local levels in all three groups best fitted with quadratic functions (Figures 7 and 8). The corresponding equations for the functions and F values were: $y= 632.85 - 15.984x + 2.079x^2$, $R^2 = 0.871$, $F\ (8, 136) = 15.00$, $p <0.01$, for the global level of Chronological age-matched group; $y = 781.90 - 77.663x + 1891x^2$, $R^2 = 0.604$, $F\ (8, 136) = 96.55$, $p <0.01$, for the local level of Chronological age-matched group; $y = 710.59 - 17.834x + 2.236x^2$, $R^2 = 0.749$, $F\ (8, 136) = 4.45$, $p <0.05$, for the global level of the SRD group; $y = 872.51 - 81.970x + 8.6105x^2$, $R^2= 0.631$, $F\ (8, 136) = 48.50$, $p <0.01$, for the local level of the SRD group; $y = 796.67 - 25.932x + 3.46780x^2$, $R^2 = 0.917$, $F\ (8, 135) = 9.57$, $p <0.01$, for the global level of the Reading age-matched group; and $y = 991.65 - 97.431x + 10.880x^2$, $R^2 = 0.676$, *F(8, 136) = 39.74, p <0.01,* for the local level of the Reading age-matched group.

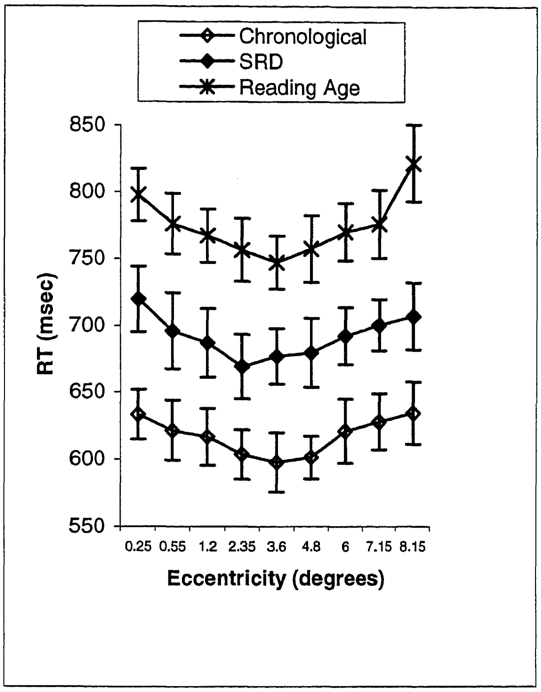


Figure 7. Mean RT as a function of reading group and eccentricity for the global level in Experiment 1.

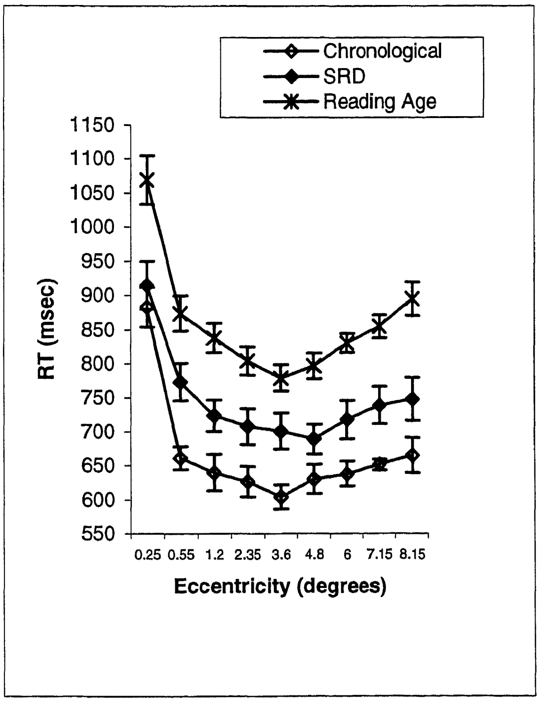


Figure 8. Mean RT as a function of reading group and eccentricity for the local level in Experiment 1.

The results of Experiment 1 show that the global level was identified faster than the local for all three groups across the retina. The three groups had the same response patterns. The three groups' results formed quadratic functions across eccentricity. This shows that in size/eccentricity uncertainty condition when eccentricities of global and local levels are equalised, the global level was processed faster than its local components. The pattern of response showed that as eccentricity increased, the RT decreased for both the global and local levels proportionally up to a certain eccentricity, however, any further increases in eccentricity increased the RT of both levels of the stimuli.

Similar analysis to the RT data was conducted on the accuracy data, where the variables and levels of variables were similar to the RT analysis. The results of accuracy analysis were exactly in line with the RT analysis and did not show any speed-accuracy trade-off. This was supported by Pearson's correlational analysis between RT and error rates *($r = 0.21$, $p < 0.01$).* The overall proportion of errors for verbally identifying the fixation stimulus was less than 0.05% across all four experiments. This suggested that the children did fixate centrally during the testing. Analysis with the corresponding *F* values can be seen in Appendix F.

The results of Experiment 1 show that under size uncertainty condition and when the eccentricities of both the global and local levels are equalised, the global level is processed faster than the local part. The results fail to support Kinchla and Wolfe's (1979) findings that the order of processing changes when a certain size is reached. The current results support the findings of Amirkhiabani and Lovegrove

(1996). The reason for the difference between the current findings and those of Kinchla and Wolfe (1979) was that in the earlier study, the variable of eccentricity was not controlled, whereby both levels of the compound stimuli used were not equalised in eccentricity.

The current finding does not agree with Navon and Norman (1983) about the non-significant difference presenting stimuli of different sizes to different eccentricities. This is illustrated by the quadratic patterns formed by both the global and local levels as shown in Figures 4 to 8. This shows that the RT for both decrease with eccentricity up to a certain eccentricity and then both increase. It is noted that Experiment 1 compared RT to nine different eccentricities, whereas Navon and Norman (1983) only compared two eccentricities. Using nine different eccentricities is thought to provide more information about any variations of RT across eccentricity than comparing only two eccentricities.

The primary results of this experiment show that the speed of processing of SRD for both global and local information was an average of approximately 85 milliseconds slower than the Chronological age-matched group. Additionally, due to developmental disadvantage (while having adequate reading ability) Reading age-matched were 96 milliseconds slower than the SRD group. The results do not support the transient deficit hypothesis, which proposes that the transient deficit may cause SRD to have a problem in processing wholes (global), for all three groups identified the global level faster than the local.

In concluding, it appears from these results that SRD children do not have a problem in processing wholes as compared to processing parts, for a difference in the processing of wholes by the SRD group was not found. The results fail to support the transient deficit hypothesis, which leads to the prediction that the SRD children will have a weaker performance at the global level. However their performance was significantly slower than the Chronological age-matched group.

This result provides an avenue for further investigation for size and eccentricity may have a fundamental influence on processing images. The aim of Experiment 2 and Experiment 3 is to examine the role of eccentricity and size independently from each other. The transient sub-system is suggested to be associated with peripheral vision and low spatial frequencies. This leads to the view that SRD children may have a problem in peripheral vision as opposed to central, and when processing large stimuli as opposed to small.

Additionally Experiment 2 and 3 may be able to explain the nature of the quadratic functions found in Experiment 1. With the compound stimuli used in Experiment 1, any increase in eccentricity had a corresponding increase in size. The pattern of RT for the global and local levels and the quadratic functions found in Experiment 1 could be explained due to the effect of eccentricity, effect of size or due to a combination of these two effects. The aim of the second experiment was to examine the variable of eccentricity independently of the variable of size. This was possible by using, simple letter ‘C’ stimuli in the second experiment.

CHAPTER 3: EXPERIMENT 2- ECCENTRICITY

3.1 Literature Review

Physiological and psychophysical studies support the notion that spatial resolution and visual acuity are superior in the fovea compared to the periphery (DeValois & DeValois, 1988). Carrasco et al. (1995) found that eccentricity affected performance on a visual search task as errors increased with increasing eccentricity. Carrasco, McLean, Katz, and Frieder (1998) found a difference between the central and peripheral vision in a visual search paradigm.

A number of other researchers have found that RT increases as the stimulus appears at more peripheral eccentricities than the central (Carrasco et al., 1995). In order to compare with the eccentricities used in Experiment 2, Carrasco et al. used the target positions of 0.7°, 1.6°, 2.1°, 2.6°, 2.9° and 3.5 ° of visual angle away from the fixation point. It is also suggested that peripheral locations of the retina are associated with low spatial frequencies, while central locations of the retina are more specialised in processing high spatial frequencies (De Valois, Yund, & Hepler, 1982).

Various other psychophysical researchers (Bennett & Banks, 1987; Bouma, 1970) have found that information about the features of a stimulus deteriorates as a function of eccentricity (Donk, 1995). For example, Rentschler and Treutwin (1989 cited in Donk, 1995) found that precise feature information is achievable in the foveal vision, but at the location about 2° away from the fovea participants were unable to discriminate between two mirror-image gratings. Saarinen (1987 cited in Donk, 1995) suggested similar results using short line segments as stimuli, and states that these results supported the notion that peripheral locations of the retina (locations with higher eccentricity) are inferior to central vision. Both studies indicate that acuity decreases smoothly with eccentricity. Donk (1995) investigated whether eccentricity of the stimuli affects RT. Donk (1995) found that in an absence-search task, RT decreased as the stimuli was presented further from the fovea, but in feature-search tasks no such effect was found.

Other researchers who have investigated perceptual differences between SRD and normal readers include Grosser and Spafford (1990) who found a lower threshold of light intensity in the peripheral retina fields of normal readers in comparison to SRD. Grosser and Spafford hypothesised that the rods and cones of the retina have an important role to play in SRD. These workers suggested that SRD detect colour in their peripheral retina more proficiently than normal readers and that SRD have an unusually high cone density in the peripheral retina.

Experiment 2 is targeted to study the retinal sensitivity of the SRD group in comparison to the control groups. An elaboration of the aims of the second experiment is the next section. Experiment 1 used compound stimuli in order to examine any differences between the three groups with regard to global/local processing. In the first experiment the stimuli sizes were randomised, however in Experiment 2 simple alphabet letter 'C's was shown in blocks of the same size.

3.2 Experiment Aims

Following the transient deficit hypothesis, it could be proposed that SRD may experience difficulties in processing peripheral information where their weak transient channel predominates. It is suggested that the transient system is more sensitive to stimuli that fall into the peripheral areas, as this is where low spatial frequencies are involved. It could therefore be expected that SRD as compared to their age-reading cohort may experience difficulties when processing visual information presented further from the retina. The purpose of the second experiment to be reported is to examine whether RT deteriorates as a function of eccentricity. Eccentricity refers to the relative location of a visual object from the viewer's fixation point.

In Experiment 1, any increase in size of the stimulus had a proportional increase in eccentricity. Experiment 2 controls the variable size in order to examine any influence on eccentricity. From the results found in Experiment 1 the pattern of RT to the global and local levels, and the quadratic functions found could be due to variations in eccentricity, or size, or a combination of both effects.

The aim of Experiment 2 was to examine the possible effect of eccentricity, independently of the effect of size by using a normal single letter 'C' or reverse 'C' of a fixed size projected to different locations across the retina. The possible effect of size is examined by using four different stimuli sizes in four separate blocks. It is expected that RT will increase as size decreases and that the SRD group may be slower than the Chronological age-matched in peripheral vision. It is expected that the two control groups will have a similar performance when processing central information. The SRD group may be the same as the other two groups in processing central information, however, SRD are expected to be slower than the control groups in processing peripheral information.

3.3 Method

Experiment 2 involved the same 54 participants and apparatus as Experiment 1. All the details of the method of this experiment was similar to Experiment 1, except the stimulus which was a single alphabet letter 'C' or reverse 'C' and not a compound stimulus (see Figure 9).

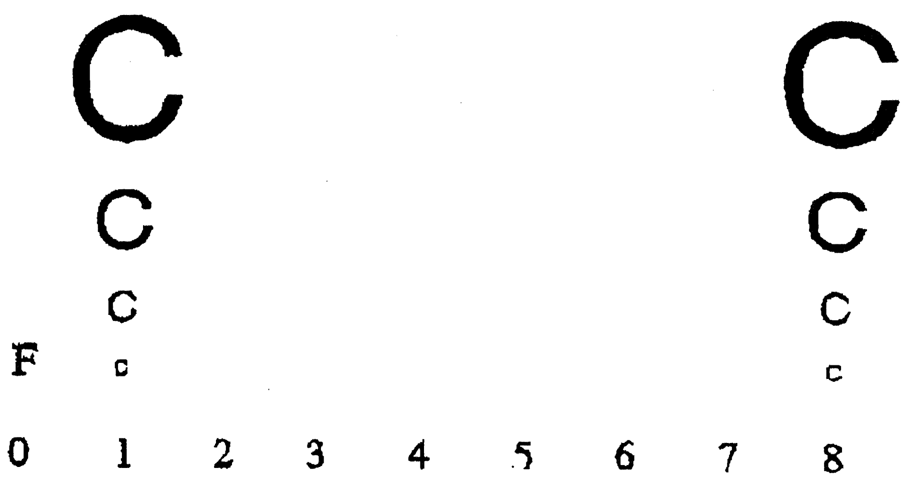


Figure 9. Schematic representation of the stimulus conditions for Experiment 2 drawn approximately to scale. Four sizes of the letter 'C' (shown) or a mirror-image 'C' were presented at one of nine retinal locations; 0 degrees (fixation) to 8 degrees in the periphery in one-degree steps. The stimuli are shown at two of these retinal locations.

The tutorial and practice session took approximately 3 minutes. The practice session had one of the four sizes available and this size was randomly chosen and counterbalanced across the participants. Four different sizes (1.20°, 0.6°, 0.3°, 0.15°) were not mixed but were presented in separate blocks to examine the possible effect of variations in size across the retina or interaction of size and eccentricity.

The three groups were asked to identify the direction of the opening of the normal single letter 'C' or reverse 'C' which was projected onto the computer monitor and across nine locations of the retina (0°, 1°, 2°, 3°, 4°, 5°, 6°, 7 °, 8°). The task for participants was to identify whether the letter opened to the left or the right. In each trial a simple letter 'C' or reverse 'C' of a fixed size was projected to either the highest or lowest position of one of the nine eccentricities. It should be emphasised that the stimulus used was a simple alphabet letter 'C' and not a compound stimulus where the global 'C' is made up of local 'O's or 'C's.

The stimulus in the second experiment was a fixed size of a single alphabet letter 'C' or reversed 'C' presented to 2.36° straight up or down of the fixation point in one block of trials, and to 7.15° straight up or down of the fixation point in another block of the trials. Therefore the stimulus was presented neither to the left nor to the right visual field.

The experiment consisted of eight randomised experimental blocks (two blocks for each stimulus size), providing a total of 54 trials in each block. The blocks were counterbalanced across the participants. Participants pressed two specially marked keys on the keyboard to identify the opening of the letter 'C' depending if the stimulus was a 'C' or reverse 'C'. Central fixation was ensured using the same procedure as in Experiment 1. Stimuli were presented above or below the central fixation point and were not presented to either the right or the left visual fields. Response accuracy and RT were recorded. The time taken to conduct Experiment 2 was approximately 40 minutes.

3.4 Results and Discussion

The reaction time analysis was based on correct responses. There was an average of 4% of trials in which responses were in error, for the Chronological age-matched, 5% for SRD and 7% for the Reading age-matched and these were removed prior to analysis.

All the main effects and interactions discussed were significant *($p<0.05$)*. There was no trade-off between RT and accuracy for correlational analysis between-subjects' RT and error rates revealed that the RT analysis could not be attributed to a speed-accuracy trade-off *($r = 0.12$, $p<0.01$)*.

A 3-way repeated-measures ANOVA for RT was conducted which consisted of Reader Group (Chronological age-matched, SRD, Reading age-matched) as the between-subjects factor, and Eccentricity (0°, 1°, 2°, 3°, 4°, 5°, 6°, 7°, 8° degrees) and Size (0.15°, 0.30°, 0.60°, 1.20°) as the within-subjects variables. This produced four statistically significant results. The main effect of Reader group was significant, *$F(2, 52) = 13.49$, $p<0.001$ ($\underline{M}$=736.97, $\underline{SD}$=245.87)*. Scheffe` Post Hoc comparisons were used to identify specific differences between the three groups. Similar to Experiment 1, SRD average RT was 187 milliseconds slower than the Chronological age-matched *($p<0.01$)* and 31 milliseconds faster than the Reading age-matched *($p <0.01$)*. The Chronological age-matched group were on average 218 milliseconds faster than the Reading age-matched group *($p<0.01$)*. The pattern of RT for all there groups can be seen in Figure 13.

Reaction time decreased with increasing size, $F(3, 156) = 28.18, p<0.001$. ($\underline{M}$=737.86, $\underline{SD}$=244), and eccentricity, $F(8, 416) = 50.72, p<0.001$($\underline{M}$=738.37, $\underline{SD}$=241.25). The groups were slower to identify the smaller stimuli. The rate of this increase was greater with the smaller stimuli, as reflected by the interaction between Size and Eccentricity, $F(24, 416) = 3.58, p<0.001$. This result reflects the difficulty experienced in identifying small stimuli at the more peripheral locations. This interaction is due to the RTs to the smallest stimulus increasing more as a function of eccentricity than the other three stimuli, which have a similar eccentricity function.

Results from the Chronological age-matched group (see Figure 10) show the longest set of latency across the nine eccentricities was the 0.15° size stimulus. There were larger increases in RT at the higher eccentricities. The other three sizes had RT that were closer together with the shortest set of RT across the nine eccentricities being the largest size (1.20°) stimuli. The RT varied from approximately 530 milliseconds to 790 milliseconds.

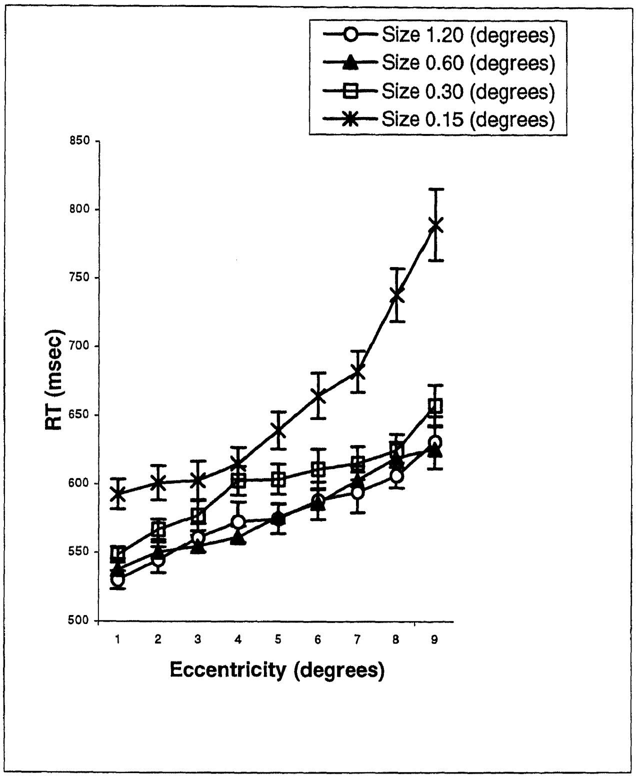


Figure 10. Mean RT as a function of eccentricity and size for the Chronological age-matched group in Experiment 2.

The SRD group also had the longest set of latencies across the nine eccentricities with 0.15° size stimuli (see Figure 11). From this set of latencies the RT had greater increases at higher eccentricities. The shortest set of latencies across the nine eccentricities was the 1.20° size stimuli. Larger sizes were identified faster than smaller. As the stimuli were presented further from the fovea RT increased and the results formed an increasing linear function. The RT varied from approximately 710 milliseconds to 910 milliseconds.

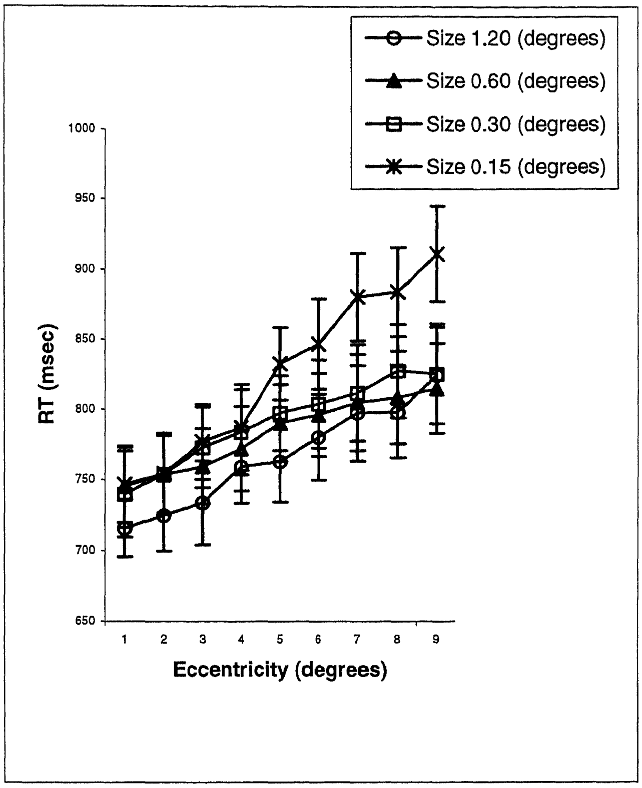


Figure 11. Mean RT as a function of eccentricity and size for the SRD group in Experiment 2.

Figure 12 illustrates that the Reading age-matched group had a similar pattern. The longest set of latencies across the nine eccentricities was the 0.15° size stimulus. The RT increases were greater at the higher eccentricities. Sizes 0.60° and 1.20° had RT times that were closer together with the shortest set of latencies across the nine eccentricities being the 1.20° size stimuli. The RT varied from approximately 700 milliseconds to 1010 milliseconds.

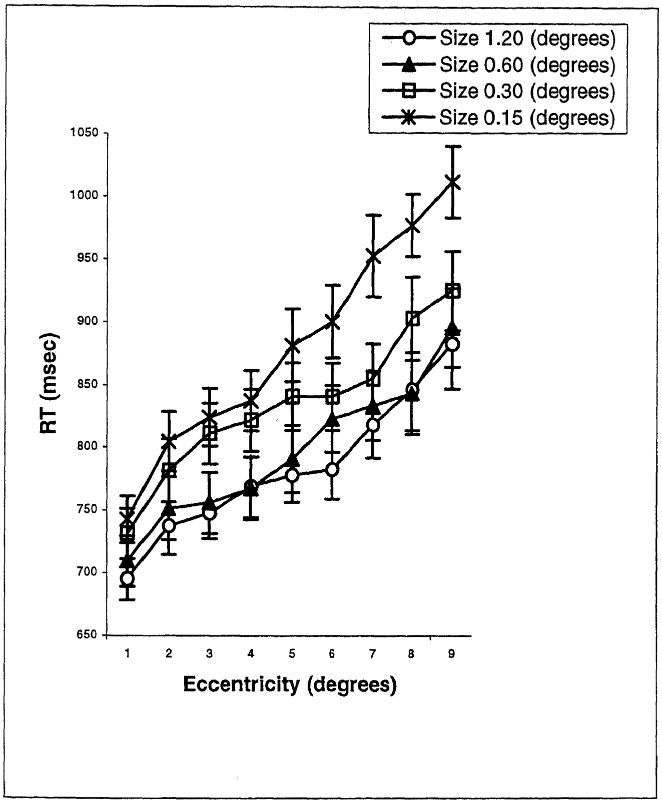


Figure 12. Mean RT as a function of eccentricity and size for the Reading age-matched group in Experiment 2.

To summarise (see Figures 10-12), for all three groups a similar pattern was found were as eccentricity increased, the RT increased for all four sizes. The RT was faster for the larger stimuli than the smaller stimuli. All groups were faster in processing centrally as compared to peripherally. It was expected that the SRD group may be different from their control counterpart, but this was not the case.

The results show that the overall speed of processing increases with increasing eccentricity and stimulus size for all three reading groups. All three groups pattern of RT results best fitted with increasing linear functions (Figures 10-13). The means used for each group can be seen in Figure 13 and are calculated by averaging the means of the three graphs in Figures 10-12. These values were, $y = 548.00 + 13.644x$,

R^2 = *0.980, F(8, 136) = 6.51, p <0.05,* for Chronological age-matched; and y = *736.91 + 13.32x,* R^2 *= 0.990, F(8, 136) = 14.10, p<0.01, for SRD ; and y = 732.59 + 438x,* R^2 *= 0.981, F (8, 136) = 10.60, p< 0.01,* for the Reading age-matched group.

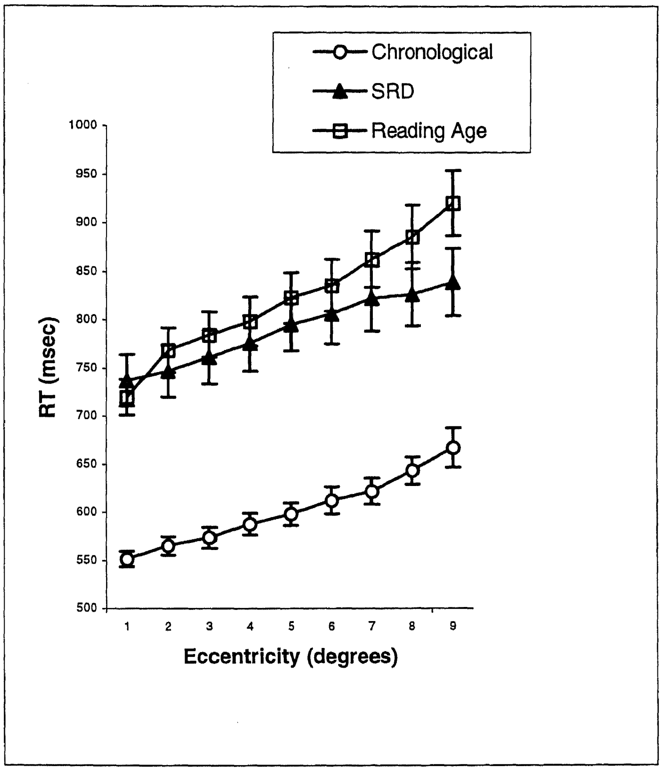


Figure 13. Mean RT as a function of eccentricity and reading group in Experiment 2.

Experiment 2 shows that SRD do not experience greater difficulty in the peripheral compared to the two control reading groups. Experiment 3 will examine whether in comparison to normal readers SRD respond differently to variations in size of the stimulus.

CHAPTER 4: EXPERIMENT 3 - STIMULI SIZE

4.1 Literature Review

The third experiment to be reported examines the effect of variations in size of the visual image across the three groups using simple letter stimuli. Schultz and Eriksen (1978) manipulated the size of stimuli and found that RT decreased as the target size increased. However the researchers used a restricted range of stimulus sizes (0.14° to 2.14°). Schultz and Eriksen (1978) claim these results support the view that the visual system differentiates gross figure-ground very early on in processing while discrimination of fine detail occurs later on (global-to-local). Intuitively it would be expected that the speed of discrimination should increase as the size of stimulus increases. The investigators concluded that when a target is big enough, there is no further gain in processing speed (Schultz & Eriksen, 1978).

More recently, Chung, Mansfield, and Legge (1998) investigated the effect of eight print sizes on reading speed at six different eccentricities, using participants who had normal peripheral vision. They found similar findings to the Schultz and Eriksen's (1978) study where reading speed increased with the print size up to a certain size and then beyond this size, speed of processing reached a plateau.

Amirkhiabani (1998) found that the relative size of global and local levels affected both global advantage and interference when presented to the peripheral location. Amirkhiabani (1998) suggested the possibility that there could be an optimal relative size of global and local levels, which may produce the largest interference of global/local interference.

4.2 Experiment Aims

The third experiment manipulates the variable of size in order to examine whether SRD children experience difficulties as the size of stimuli increases. If the transient deficit hypothesis is correct, and SRD have a weak transient channel, processing involving low spatial-frequency may lead to difficulties in detecting larger stimuli in comparison to smaller stimuli.

The aim of Experiment 3 was to investigate the role of size independent from eccentricity. To examine any differences, seven different sized stimuli were projected to two fixed locations on the retina.

4.3 Method

The same participants were involved in Experiment 3 as in Experiments 1 and 2. All details of the method were the same as the two previous experiments except for the following differences. In order to examine any possible interaction between eccentricity and size of the stimulus, the stimuli were projected to two locations on the retina (2.36° and 7.15°). There were seven visual angle sizes (0.3°, 0.6°, 0.9°, 1.2°, 1.5°, 1.8°, and 2.1°). To manipulate the possible effect of eccentricity, the seven sizes of stimuli were projected to two different eccentricities. The seven visual angles were projected to either the upper or lower location of one of the two eccentricities. The stimuli were presented directly above and below the central line between the right and left visual fields. Stimuli were not projected to either the right or to the left visual fields.

There were three separate blocks for the two eccentricities (2.36° and 7.15°). In each block there were five presentations of each of the seven stimulus sizes in random order, which is a total of 35 trials per block. The experimental blocks were counterbalanced across participants. The task for participants was to respond to whether the single 'C' had a left or right opening by pressing the two specially marked keys on the keyboard. Participants responded to right or left facing single 'C's or reversed 'C's. A simple alphabet letter 'C' was used and not compound stimuli such as in Experiment 1 (see Figure 14). Similarly to Experiment 1 and 2, this experiment ensured central fixation using the same procedure. Before the experimental blocks, tutorial and practice sessions were conducted and this took approximately 3 minutes. Similarly to the previous experiments the response accuracy and RT were recorded. The time taken to conduct Experiment 3 was approximately 15 minutes for each participant.

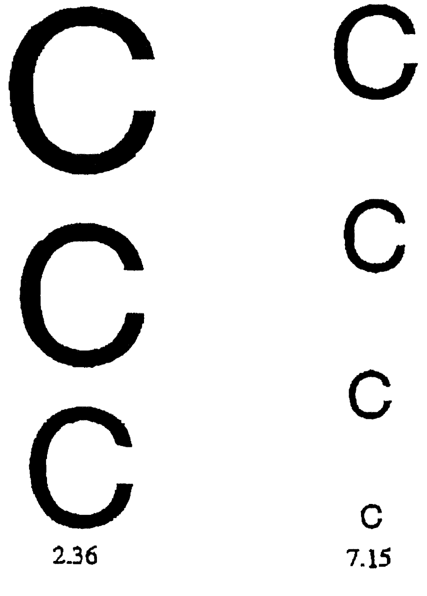


Figure 14. Schematic presentation of the stimulus conditions for Experiment 3. Seven sizes of the letter 'C' (shown) or mirror-image 'C' were presented in blocks at one of two retinal locations; 2.36 and 7.15 degrees above and below the focal point.

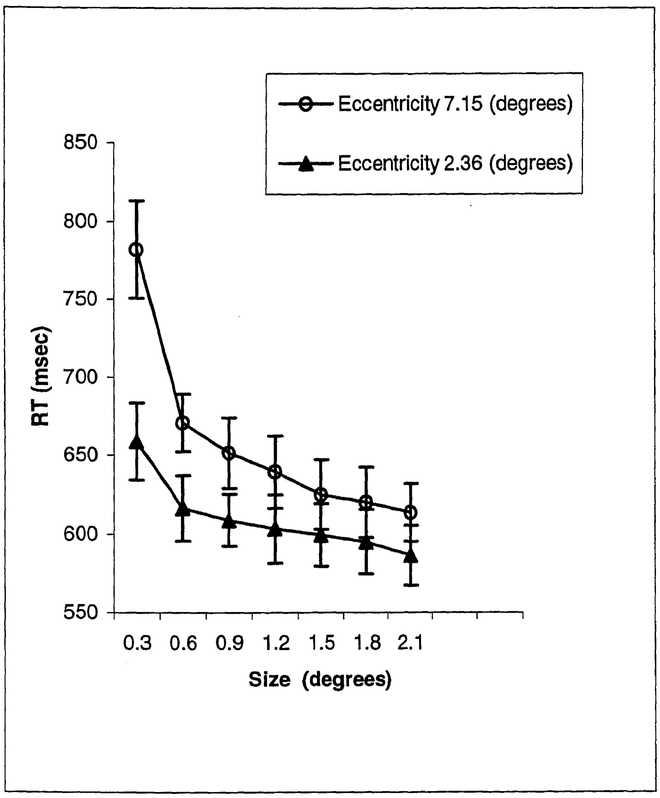
The design of the third experiment is an extension of Experiment 2 using the same single letter 'C' stimuli however the two experiments have different aims and methodology. In Experiment 2, the variable of size was controlled in order to examine the variable of eccentricity. The variable of size was controlled by using a fixed size of stimuli in blocks presented to various location of the retina. Experiment 3 was conducted to control the variable of eccentricity while the variable of size was manipulated. In Experiment 3, eccentricity was held constant by presenting fixed size stimuli to two eccentricities. Due to the differences in aims and variables being controlled, two separate vision experiments were required.

4.4 Results and Discussion

Trials in which responses were in error (average of 3% for all three groups combined) were omitted prior to the RT analysis. The 3-way repeated measured ANOVA was performed on the RT and had Reader group (Chronological age-matched, SRD, Reading age-matched) as the between-subjects variable, and Size (0.3°, 0.6°, 0.9°, 1.2°, 1.5°, 1.8°, 2.1°) and Eccentricity (2.36° and 7.15°) as the within-subjects variables. The main finding was a significant effect of Size, $F(6, 18) = 62.05$, $p <0.001$ ($\underline{M}=725.25$, $\underline{SD}=227.5$) with RT being faster when stimuli were larger. Eccentricity was significant, $F(1, 53) = 76.47$, $p<0.001$ ($\underline{M}=724.44$, $\underline{SD}=229.54$), stimuli projected closer to the fovea were detected faster than the stimuli further from the fovea for all three groups. This is consistent with the Eccentricity effect found in Experiment 2. Eccentricity did interact with Size, $F(6, 318) = 11.88$, $p<0.001$ indicating that the rate of increase in RT changes with size. Furthermore the main effect of Reader group was significant, $F(2, 53) = 17.72$, $p <0.001$ ($\underline{M}=724.11$,

<u>SD</u>*=231.2)* and a Group by Size interaction indicated that a difference existed between the groups over the four sizes, $F(12, 318) = 2.81, p = 0.001$.

The stimuli presented to 2.36° were identified faster than when presented to 7.15° with the difference being approximately 30 milliseconds for the Chronological age-matched group (see Figure 15). The smallest size (0.3°) had a markedly longer RT for both 7.15° and 2.36° eccentricities but particularly for the 7.15° eccentricity. The pattern of RT formed a decreasing logarithmic function as RT decreased with increasing size.



<u>Figure 15</u>. Mean RT as a function of size and eccentricity for the Chronological age-matched group in Experiment 3.

Figure 16 illustrates that SRD had a difference between 2.36° and 7.15° of approximately 40 milliseconds with 2.36° having the faster RT. The smallest 0.3°

size at 7.15° eccentricity had the longest RT. This was a marked difference compared to the other RT. The Reading age-matched group at the 2.36° eccentricity had a faster RT than 7.15°. Repeatedly there was a markedly longer RT with the 0.3° size, and eccentricity 2.36° had faster RT than 7.15° (see Figure 17).

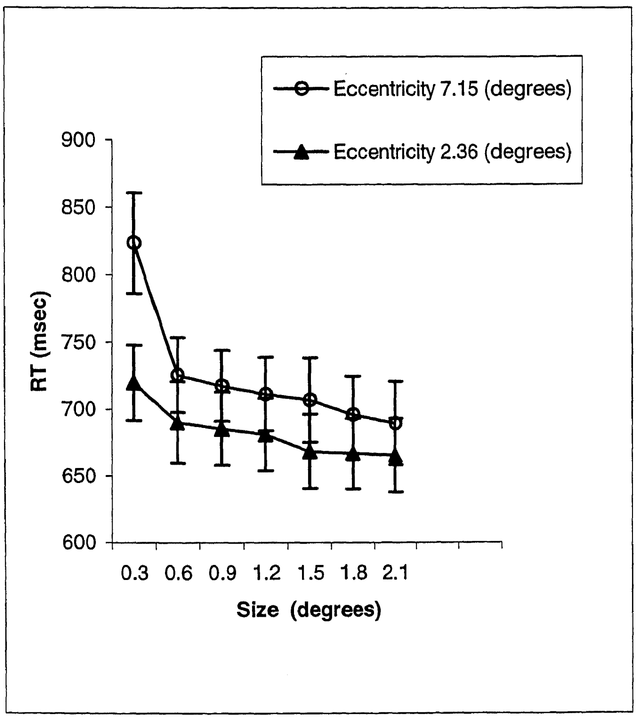


Figure 16. Mean RT as a function of size and eccentricity for the SRD group in Experiment 3.

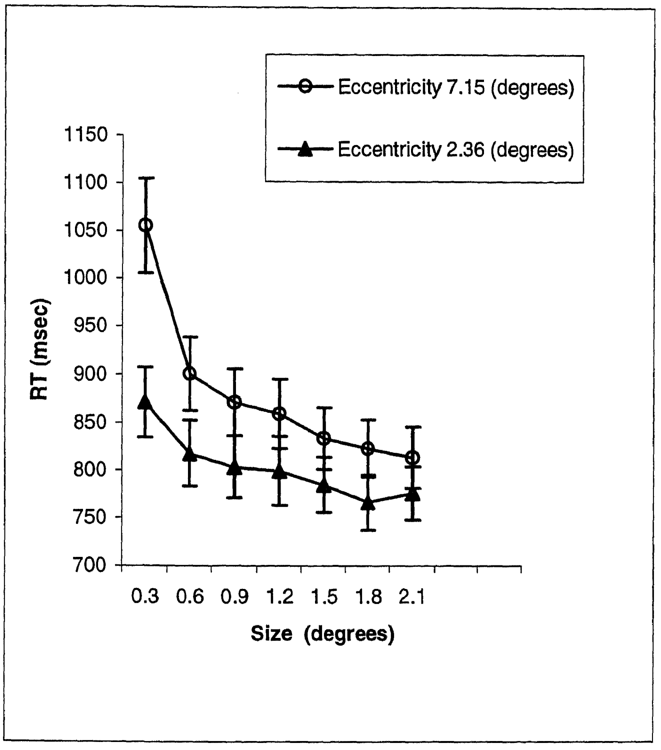


Figure 17. Mean RT as a function of size and eccentricity for the Reading age-matched group in Experiment 3.

Figure 18 shows that the pattern of average correct RT for all three groups was the same, eccentricity 2.36° where the larger sizes had the shorter RT. The longest RT was for the smallest size (0.3°). To summarise the main findings, 2.36° had shorter response latencies than 7.15°, and RT decreased with increasing eccentricity for all three groups. When eccentricity is controlled, RT decreases linearly with size. All three groups had a faster performance when processing centrally rather than peripherally.

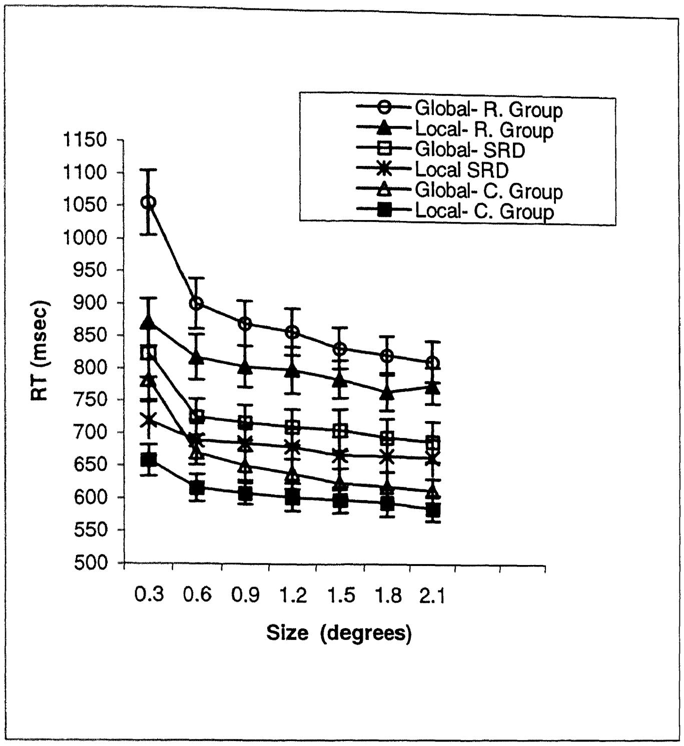


Figure 18. Mean RT as a function of size, eccentricity and reader group in Experiment 3. In the legend the global level is eccentricity 7.15° and the local level is eccentricity 2.36°.

Specific group differences between the three groups were identified by using Scheffe´ Post Hoc comparisons. The results showed that the SRD group was an average of 138 milliseconds ($p < 0.01$) faster than the Reading age-matched group and 70 milliseconds ($p < 0.05$) slower than the Chronological age-matched group at processing the simple letter stimuli. The Chronological age-matched group performed on average 210 milliseconds ($p < 0.01$) faster than the Reading age-matched group.

The patterns of RT by variations in size fitted best with decreasing logarithmic functions for both small, $y = 609.80 * x^{-5.3578} e^{-2}$, $R^2 = 0.934$, $F (6, 102) = 9.39$, $p < 0.01$; and large, $y = 656.56 * x^{-0.11699}$, $R^2 = 0.916$, $F (6, 02) = 50.79$, $p < 0.01$, eccentricity conditions of Chronological age-matched; small, $y = 682.81 * x^{-3.9697} e^{-2}$ $R^2 = 0.961$, $F (6, 02) = 5.54$, $p < 0.01$; and large, $y = 724.06 * x^{-8.0952} e^{-2}$ $R^2 = 0.856$, F

(6, 102) = 10.72, p<0.01, eccentricity conditions of SRD; and small $y = 812.50 * x^{-6.5946} e^{-2,}$ $R^2 = 0.983$, $F(6, 102) = 4.95$, $p < 0.05$; and large, $y = 882.30 * x^{-0.11469} e^{-2}$ $R^2 = 0.921$, $F(6, 102) = 23.23$, $p < 0.01$, eccentricity conditions of Reading age-matched groups. RT and accuracy analysis was compared in order to eliminate any speed-accuracy trade-off. This was confirmed using Pearson's correlational analysis and error rates ($r = 0.25$, $p < 0.01$). The accuracy analysis can be found in Appendix F.

Overall the results of this experiment show all three groups have the same pattern of RT, whereby large stimuli were detected faster than small stimuli. This does not support the transient deficit hypothesis because they do not experience increased difficulty with the processing of larger stimuli where low spatial frequencies are involved. Similarly to the previous experiment, SRD individuals were significantly slower than the Chronological age-matched group but faster than the Reading age-matched group.

The results of Experiment 2 and 3 unravel the nature of the quadratic function found in Experiment 1. When the variable of size was controlled and eccentricity was changed, the pattern of RT made an increasing linear function as depicted in Experiment 2. When the variable of eccentricity was controlled and the variable of size was manipulated, the patterns of RT made a decreasing logarithmic function. If variables of size and eccentricity were changed, in a similar way to Experiment 1, patterns of RT would form a quadratic function that has resulted from adding an increasing linear function and decreasing logarithmic function.

CHAPTER 5: EXPERIMENT 4- GLOBAL AND LOCAL INTERFERENCE EFFECT

5.1 Literature Review

Attention is paid to different aspects of the environment. While attention is selective, it can also be divided to more than one task or stimulus at a time. In the classic Stroop task (Stroop, 1935, cited in Bernstein et al., 1991), participants had to focus attention on one aspect of the stimulus (colour) while another powerful aspect (meaning of the word) was competing for their attention. The two aspects of the stimulus call for incompatible responses. As discussed in Experiment 1, there are two views on the perception of parts and wholes. The first view is that the whole is built up from analysis of its parts, and the second is that the whole is perceived before the parts.

Martin (1979) used a Stroop interference task where participants had to identify the opening of the letter 'C' either at a global or local level. The researcher manipulated the goodness of the form in the Gestalt sense to investigate processing advantages. Martin (1979) found that global precedence occurred with many-element stimuli but local processing priority was found with few local elements (with differing sparsities). The results imply that sparsity impedes global precedence.

Navon (1983) replied to this claim by undertaking a similar study with geometric figures in which the size and sparsity of the local elements were manipulated. Navon's results were consistent with past findings of global precedence. The difference between the two studies may be explained by the fact that the two studies used different compound stimuli (geometric versus letters) of different sizes and were conducted under different task conditions (selective versus divided attention).

Antes and Mann (1984) state that globality and retinal eccentricity are still confounded as suggested by Navon and Norman (1983). The two studies both used an interference task, however Antes and Mann (1984) used pictorial stimuli that have mutually predictable global and local levels (for example a beach scene [global level] with a boat [local level]), whereas Kinchla and Wolfe (1979) used compound letters, which have independent global and local levels. Antes and Mann (1984) found supportive evidence for global precedence when the visual angle was small and support for local precedence for larger scenes. This study also suggested that global precedence may be affected by factors such as size. Whether the stimuli were consistent or inconsistent was found to be less important for large scenes when attending to local level (rather than global level). Inconsistent global level stimuli had no interference in local processing. For the smaller scenes the global level was processed faster and was not affected by local elements when attending globally. The results replicate Kinchla and Wolfe's (1979) study that used global-local independent stimuli.

Lamb and Robertson (1988) suggested there may be an association between global advantage and global interference. They state that RT and asymmetric interference effects should covary in a systematic way, in that global advantage should be associated with global interference and the same pattern should be found locally. In Experiment 1 of Amirkhiabani and Lovegove's (1999) study, in order to examine the differences between Kinchla and Wolfe (1983) and Navon and Norman (1983), participants were uncertain about the size and eccentricity of the stimuli. Similar stimuli to that employed by Navon and Norman (1983) were used where the local elements were located along the perimeter of the global figure (equalised). In order to examine the role of eccentricity the same nine stimuli were projected to nine retinal locations. The results were that the global level was identified faster than the local in both central and peripheral locations across the retina. Consistent stimuli assisted the RT of the local processing in the central but slowed the processing peripherally. Reaction time increased for both levels up to a certain size/eccentricity, which suggested an optimum retinal location at around 2.35°.

Amirkhiabani and Lovegrove (1999) suggested that this pattern of interference effects could be attributed by variations in size of either level, variations in eccentricity or a combination of size and eccentricity of either level. The stimuli used allowed for separate manipulation of the size (size of the gap in the 'C') and eccentricity variables. They used a broad range of sizes and eccentricity, and found that the pattern is likely to be due to eccentricity rather than the gap size of the stimuli. They concluded that the results failed to find an association between size of a stimuli and global advantage.

Experiment 4 considers the affect of attention in the visual processing of SRD children by using a Stroop-type paradigm where participants were instructed to attend either to the global or local level. Interference effects have highly robust and consistent findings using a variety of stimuli (Cohen, Dunbar, & McCelland, 1990). Pomerantz (1983) states that while it may be more appropriate to use the term 'incongruity interference', 'Stroop interference' is in keeping with previous literature.

The task in the fourth experiment uses conflict between local and global levels. Participants must respond to stimuli that vary in two dimensions, one of which they must ignore. As stated previously, Navon (1977) proposed compound letter stimuli to control the independence and unpredictability of global and local features. Navon (1977) found that the global level has an inhibitory influence on the local level. The global information was available at the time of local processing but not the reverse. As was mentioned previously, SRD are prone to interference of incongruent information. For example it was suggested that a weak or sluggish transient system may fail to inhibit the sustained channel activity causing visual persistence to last longer. Experiment 4 examines the effect of inconsistent global/local information on the processing of global and local information.

5.2 Experiment Aims

The aim of Experiment 4 was to examine if there was any difference in visual processing of congruent/incongruent compound stimuli in comparison to the two control groups. Following the global precedence hypothesis, the global level will be processed prior to the local, however if SRD children experience weak transient processing, local interference/facilitation may be found when the transient system is involved.

5.3 Method

The same previously involved participants assisted in Experiment 4. All other details were similar to Experiment 1. The factor of eccentricity was controlled by equalising the eccentricities of the global and local levels, by using the compound stimuli seen in Figure 19. The 'C's and reverse 'C's had the same range of visual angles as Experiment 1. The stimuli were either congruent with both levels facing the one-way or incongruent. In this experiment participants were instructed at the beginning of each block as to whether they had to attend to the global or local levels. The circular stimuli surrounded the fixation point. The eccentricity was equal to half of the visual angle of the size of the global figure. In the global condition, participants were instructed to respond to the direction of the opening of the 'C' at the global level, and in the local condition, they responded to the direction of the 'C' at the local level. There were 13 small 'C's in the perimeter of the large 'C'.

The experiment consisted of eight randomised experimental blocks (four global configurations and four local), providing a total of 432 trials with there being 54 trials per block. Experiment 4 took approximately 35 minutes to conduct.

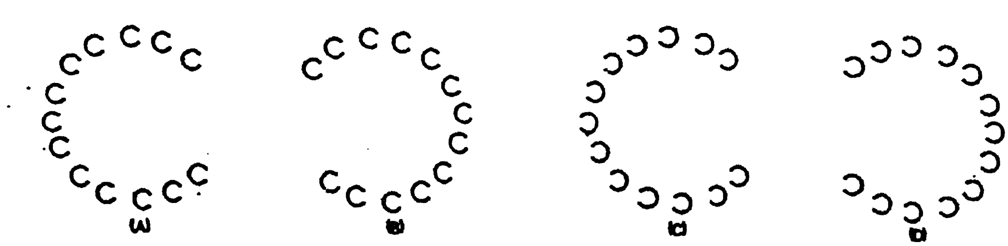


Figure 19. Stimuli used in Experiment 4 and originally used by Navon and Norman (1983).

5.4 Results and Discussion

An ANOVA with Group (Chronological age-matched, SRD, and Reading age-matched) as the between-subjects factor, and Target level (global, local), Consistency (consistent, inconsistent) and Eccentricity (0.25°, 0.55, 1.2, 2.35, 3.6, 4.8, 6, 7.15, and 8.15°) as within-subjects factors was conducted. The ANOVA produced six statistically significant results. There was a significant main effect for Target level, $F(1, 51) = 561.71$, $p<0.001$ ($\underline{M}=805.87$, $\underline{SD}=278.24$) which indicates that the global level was detected faster than the local.

Scheffe' Post Hoc comparisons were used to identify specific group differences. The main effect of Reader group $F(2, 51) = 1104.74$, $p <0.001$($\underline{M}=803.9$, $\underline{SD}=284.06$) shows that SRD individuals processed both the global and local information significantly slower than the Chronological age-matched group (on average 155 milliseconds, $p <0.01$) but faster than the Reading age-matched group (74 milliseconds, $p <0.05$). The Consistency variable, $F(1, 51) = 46.43$, $p<0.001$, (Consistent, $\underline{M}=803.9$, $\underline{SD}= 284.06$; Inconsistent, $\underline{M}=820.06$, $\underline{SD}= 282.4$), changes across Eccentricity, ($\underline{M}=805.62$, $\underline{SD}=282.3$) $F(8, 51) = 11.42$, $p<0.001$ as reflected by the interaction between Consistency and Eccentricity, $F(8, 51) = 3.32$, $p=0.001$. Additionally Consistency-by-Target level was significant, indicating that consistency changed across the two levels, $F(1, 51) =55.48$, $p<0.001$. The interaction of Eccentricity and Target level was significant, $F(8, 51) = 3.24$, $p = 0.001$.

Figure 20 illustrates the mean RT as a function of consistency and eccentricity for the Chronological age-matched group. These results formed a quadratic function as inconsistent stimuli had consistently longer RT than consistent at the global level. Local level (consistent and inconsistent) had longer RT than the global level. The RT for the local inconsistent stimuli was unusually high for the smallest eccentricity (0.25°). For the local level, as eccentricity increased, the consistent stimuli had the longer RT.

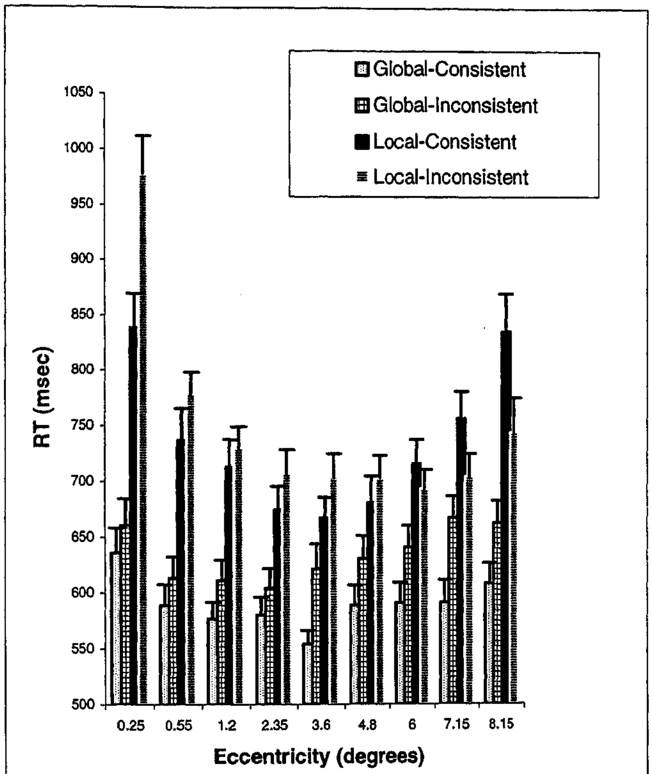


Figure 20. Mean RT as a function of size and eccentricity for the Chronological age-matched group at the consistent and inconsistent level in Experiment 4.

The results for the SRD group shown in Figure 21 show the same pattern with the global level being identified faster than the local across nine eccentricities and repeatedly the results formed a 'U' shaped quadratic function for the global level. Repeatedly, local consistent was faster for 0.25° to 1.2° eccentricity, whereas local inconsistent was faster at 2.35° to 8.15°. The Reading age-matched group (seen in Figure 22) was faster in global consistent than global inconsistent. At eccentricity

0.25° local consistent has slightly longer RT. From 0.55° to 3.6° local consistent had shorter RT, whereas from 4.8° to 8.15° local consistent had longer RT.

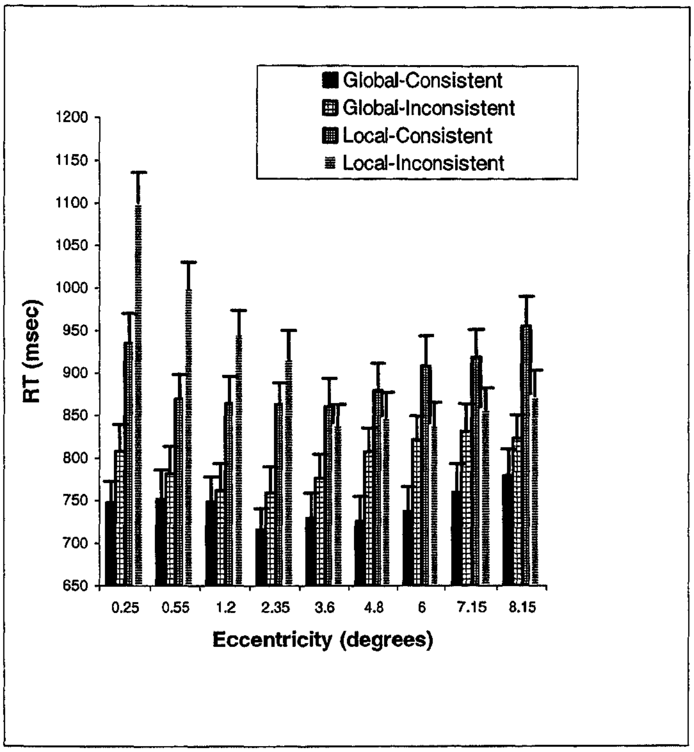


Figure 21. Mean RT as a function of size and eccentricity for the SRD group at the consistent and the inconsistent level in Experiment 4.

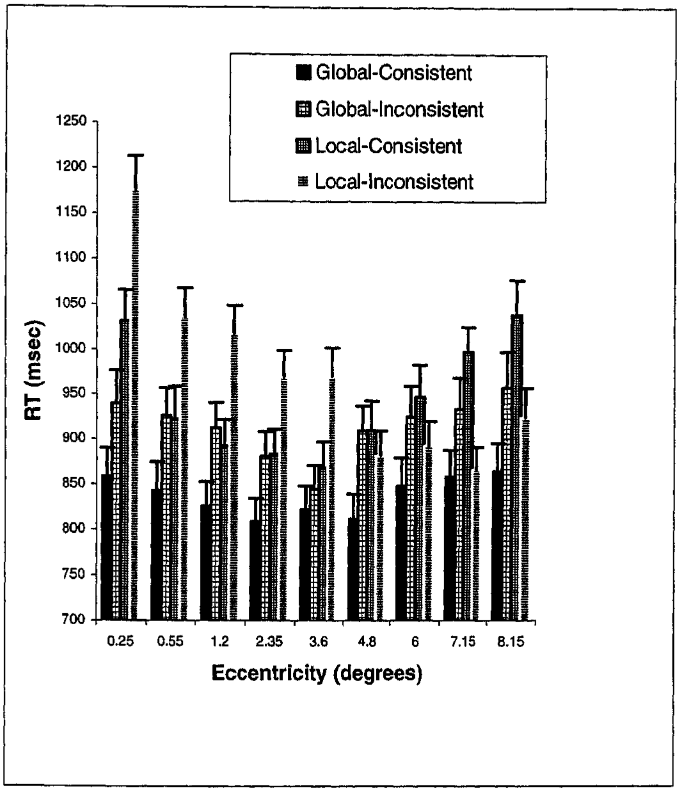


Figure 22. Mean RT as a function of size and eccentricity for the Reading age-matched group at the consistent and inconsistent level in Experiment 4.

All three groups showed a similar pattern in processing local and global levels. Similarly to the previous three experiments, the global level was detected faster than the local level across the retina and the pattern of responses to both global and local levels showed quadratic functions when the data were broken according to the consistency of the global and local levels. The consistent global level was detected faster centrally than the inconsistent local level. However in the peripheral locations, this was reversed and the inconsistent local level was detected faster than the consistent local level. There was no specific pattern found for the processing interference of the local level on the global level. In other words, there was no order in processing of consistent and inconsistent global information across the retina. This pattern was the same for all three groups.

When presented closer to the fovea the global level (both consistent and inconsistent) had the shorter RT. The corresponding equations for the functions and F values were: $y = 490.23 - 16.392x + 220.19x^2$, $R^2 = 0.813$, $F\ (8,\ 136) = 113.95$, $p<0.01$, for the global level of Chronological age-matched group; $y = 794.82 - 67.82x + 923.77x^2$, $R^2 = 0.684$, $F\ (8,\ 136) = 85.57$, $p <0.01$, for the local level of Chronological age-matched group; $y = 622.45 - 21.85x + 21.48x^2$, $R^2 = 0.636$, $F\ (8,\ 136) = 26.57$, $p <0.01$, for the global level of the SRD group; $y = 839.69 - 68.832x + 10.832x^2$, $R^2 = 0.719$, $F\ (8,\ 136) =51.94$, $p <0.01$, for the local level of the SRD group; $y = 739.97 - 19.328x + 5.88x^2$, $R^2 = 0.885$, $F\ (8,\ 135) = 10.85$, $p< 0.01$, for the global level of the Reading age-matched group; and $y = 843.48 - 182.74x + 14.391x^2$, $R^2 = 0.698$, $F\ (8,\ 136) = 48.62$, $p<0.01$, for the local level of the Reading age-matched group.

A comparison of the results of the RT and accuracy analysis using Pearson's correlational analysis and error rates ($r = 0.11$, $p <0.05$) confirmed that none of the RT analysis results could be attributed to a speed-accuracy trade-off. The accuracy analysis can be found in Appendix F.

In concluding, the results of all three groups form the same quadratic functions in reported Experiment 1. The global level had an inhibitory influence on responding to the local level in all three groups. Consistent with the three previous experiments, the average RT for SRD was slower than of the Chronological age-matched group (155 milliseconds) and faster than the Reading age-matched group (74 milliseconds).

CHAPTER 6: GENERAL DISCUSSION AND CONCLUDING REMARKS

6.1 Main Findings

The four experiments of this study have examined the visual processing of SRD children in comparison to normal readers. Global and local processing was examined in the first experiment. The second experiment compared the visual processing of the three groups across the retina. The third experiment compared the visual processing of the three groups to high and low spatial frequencies (large and small stimuli). The fourth experiment investigated the effect of incongruent information on visual processing.

Following the transient deficit hypothesis, it was expected that the SRD children may experience performance differences when processing wholes (global), as opposed to parts (local). This should have been the result due to the involvement of a weak transient channel when processing global information. The results from Experiment 1 show that the global advantage reported by Navon and Norman (1983) did not change across the groups as global precedence was found for all three reading groups with the global and local results forming quadratic functions across eccentricity. The SRD children failed to have a different performance in processing global information but were significantly slower than the Chronological age-matched group. It appears that the different findings in the Kinchla and Wolfe (1979) and Navon and Norman (1983) studies were probably due to the eccentricities of the global and local levels not being equalised in the Kinchla and Wolfe (1979) study. This result is consistent with that found in the study of Amirkhiabani and Lovegrove (1996).

It was hypothesised that the SRD group may have a deficit in processing in the peripheral retina, due to the involvement of their weak transient channel. The results of experiment 2 show that all three groups RT increased with increasing eccentricity.

From the premise that the low spatial-frequency deficits may cause difficulty in processing larger stimuli (Antes & Mann, 1984), it was interesting to note that again the transient deficit was not supported in Experiment 3 because the SRD group did not experience any processing problems in this area. A similar pattern to the previous experiments was found, where the SRD group were on average 70 milliseconds behind the Chronological age-matched group.

The results of Experiment 3, formed a decreasing logarithmic function with RT decreasing as size increased for both eccentricities. The results of Experiment 2, when size was controlled, formed an increasing linear function, whereas Experiment 3 found a decreasing logarithmic function, when eccentricity was controlled. Together the findings from Experiment 2 and 3, further explain the quadratic patterns of RT across eccentricity found in Experiment 1. When the variable of size was controlled, the patterns of RT by eccentricity formed an increasing linear function. When eccentricity was controlled, the patterns of RT by size formed a decreasing logarithmic function. When size and eccentricity proportionally increased, the patterns of RT made a quadratic function, as found in Experiment 1. This function was the total of those increasing linear and decreasing logarithmic functions reported in Experiments 2 and 3.

The aim of Experiment 4 was to examine the performance of the SRD group using inconsistent information. The pattern of results found for SRD group was no different from the two control groups. From Experiment 4, the current study found that inconsistent stimuli had a greater interference effect, and the global level, regardless of being consistent or inconsistent with the local level, was identified faster than the local level was. The results of the present study are consistent with previous research by Paquet and Merikle (1988) who found that the global aspect was identified faster and was more difficult to ignore than the local level.

The results of the present study have shed some light on visual processing differences between SRD and normal readers and on the involvement of the transient deficit hypothesis. From the four experiments conducted the results show that the SRD group had no difficulty in processing wholes in comparison to parts, peripheral as compared to central information, low spatial-frequency as opposed to high and with incongruent information. However across all four experiments, the SRD group was significantly slower than the Chronological age-matched group.

The results of the present experiments indicate that SRD were on average approximately 100 milliseconds behind the Chronological age-matched group. This finding has important implications for the design of remediation programs, in that it shows that SRD may improve their reading ability if they were provided with an additional 100 milliseconds for processing units of visual information. The difference between the results of this study and other studies that have found a transient deficit in

SRD when processing visual stimuli, may be related to fact that the variable of eccentricity was not controlled in the previous studies. A review of the possible shortcomings of the present research and possibilities for future research is addressed in the next section.

6.2 Possible Shortcomings and Future Research

Some may suggest that the results found in this study may be due to SRD children having slow hand co-ordination. As mentioned in the method section of Experiment 1, Boer and Keuss (1982) found that the directions of left and right provide a directional cue that can make responding difficult. To avoid any confusion the response keys were not counterbalanced. Furthermore, motor co-ordination is unlikely to have caused the results found, for the experiment has used very straightforward tasks.

In all four experiments, the SRD group were significantly slower in processing the visual information compared to the Chronological age-matched group, and the Reading age-matched was slower again. The current results suggested that the Reading age-matched group were developmentally disadvantaged despite sound reading abilities. Obviously if the SRD readers are 2 years behind in their reading, Reading age-matched individuals must be 2 years younger. Adding a normal reader comparison group, who are at the same reading level, assists in separating out the age-related and reading-related variables. Reading age-matched have been found to be behind in both motor skills and general knowledge, as well as having differences in the ability to process information from visual information store to short-term memory store (Lovegrove & Brown, 1978).

Eden, Stein, Wood, and Wood (1994) state that it is misleading to compare dyslexics with younger Reading age-matched controls. They claim that using the reading level matched design can make it difficult to compare this group with SRD for it has been found that older children have better visual skills (Lyle & Goyen, 1975). They also suggested that visual skills may improve with age and this means that a comparison may be misleading as the older children have the advantage in vision tasks. While the criticisms concerning using Reading age-matched control groups is acknowledged, the methodology adopted by the majority of research in this area uses both Chronological age-matched and Reading age-matched control groups.

The pattern of RT for the three groups found in the current study could be due to the possible effect of a lower average Verbal and Performance IQ for both the SRD group and the Reading age-matched group compared to a substantially higher average IQ for the Chronological age-matched group. The slower RT for the SRD group could be related to the difference in the lower average IQ of this group or some deficit in visual processing or it could be a combination of both factors, or none of these factors. It is acknowledged that the slower RT of the SRD group could be partially related to the lower average of the IQ of that group. The difference in RT patterns between the Chronological age-matched group and the Reading age-matched group is likely to be related to the maturational effect.

Amirkhiabani (1998) has suggested a difference in RT to stimulus projected to right and left visual fields as these visual field are associated with left and right hemispheres, respectively. The results of the four experiments show that in all three groups 'C's were detected faster than reverse 'C's. The ratio of right to left handed children in this study was 4 to 1. Following Amirkhiabani's (1998) findings this study's results could be related to the dominance of the left hemisphere or could be related to the dominance of the right hand as 'C's were responded with the right hand and reverse 'C's were responded with the left hand.

The tasks used to date in this area of research suffer from attentional and performance factors for they require vigilance and attention. It is noted that participants had some difficulty in attending and maintaining their motivation for the experiments. The potential confounds of boredom, distractibility and tiredness in visual research must be considered in future visual deficit studies (Hayduk et al., 1996). The difficulties that SRD children face make them more vulnerable to such interference (Hayduk et al.). They claim that studies such as Martin and Lovegrove's (1987), which asked SRD to maintain attention for over 1500 milliseconds is placing too great a strain on the children's ability to maintain concentration and motivation.

As discussed in Chapter 1, sluggish processing of visual information experienced by SRD may create a timing disorder that does not allow for the efficient and rapid processing of successive saccades, such as is required in reading. Also addressed in Chapter 1, these results could reflect a visual deficit sub-type and this leads to the notion of a deficit being confirmed in other sensual modalities. Obviously before definite conclusions cannot be made, as further study is required.

For a more complete understanding of how a transient sub-system deficit affects SRD children, the use of both single words and continuous text, which has a closer approximation to the actual process of reading, must be further explored. Further examination would determine if SRD actually do experience greater errors when having to integrate information from successive fixations as opposed to single images, as used in the current study. Following Breitmeyer's (1975) explanation given in Section 1.3.3, when SRD have to integrate both peripheral and central information, excessive visible persistence may result in a superimposition of fixations. If this effect is found in more reading related tasks, firstly this will have implications for remedial techniques, and secondly this may provide support for the transient deficit hypothesis.

Lovegrove and Macfarlane (1990) have found that SRD were more accurate in a one-word at a time condition as opposed to a whole line condition. However there is still an avenue for further research to be conducted on how a potential transient deficit relates to a more reading-like situation. From the Lovegrove and Macfarlane's study, the preliminary results for the transient deficit hypothesis are encouraging. It is noted that the current research findings are limited by using compound and single letters, and therefore has been unable to further the research findings with regard to processing continuous test. The importance of varying the mode of visual presentations to the whole word condition is recognised. While it is thought that future research should continue to examine processing differences in SRD children, it is acknowledged that future research may turn to experiments that have more construct validity due to being a closer approximation to actual reading.

There are many important areas for future research to examine. Future investigations should consider a range of other variables such as the role of handedness and of hemispheric processing on global and local stimuli in order to not exclude the influence of these variables. Another area to consider is monitoring of eye movements during visual processing studies in order to eliminate any possible effects that the SRD children may be experiencing from having less stable fixations.

Reading is a process that requires the successful integration of multiple fixations. An important area for future research to consider is the finding that SRD have a tendency to experience fixational drifts (Eden, et al., 1993). This group measured binocular fixation and phonological recoding during reading of SRD and controls. These researchers found support for a transient deficit and found that SRD tend to neglect the left-visual field.

Furthermore it is noted that this study did not undertake any other combination of the proportion of the sizes of local to global level (1 to 8). Future research could examine whether this affects the performance differences found between SRD children and their normal reading counterparts. This study will now conclude with a summary.

6.3 Summary and Concluding Remarks

This study investigated if there was a difference in visual processing between SRD and normal readers using the premises of the transient deficit hypothesis. In this study the transient deficit hypothesis was examined using the global precedence paradigm with stimulus that had eccentricity of its global and local levels equalised. Meanwhile the sensitivity of different parts of the retina of the SRD children was compared to control groups. In addition, the role of size (Experiment 3) and incongruent information (Experiment 4) were also examined. The results show that SRD children do not have any problems in processing wholes in contrast to parts, and in processing low spatial frequencies in contrast to high. The sensitivity of the different locations on the retina in SRD children was similar to normal readers. SRD individuals also showed a similar pattern and there was no difference between SRD and normal readers RT in processing high in contrast to low spatial frequencies, and in processing congruent in contrast to incongruent visual information.

If the transient deficit hypothesis is correct, SRD should have shown difficulties in processing global stimuli in comparison to local, stimuli in periphery in contrast to centre of the visual field, in larger stimuli compared to smaller and incongruent compared to congruent stimuli. However, this was not the case. Therefore the results do not support the premises of the transient deficit hypothesis. The significantly slower reaction time of SRD compared to Chronological age-matched group could be related to a deficit in visual processing of SRD individuals or the difference in average IQ of the two groups, or both, or neither.

The overall results of the four experiments does not support the transient deficit hypothesis in the sense that the transient channel is suggested to be associated with the processing of wholes; associated with processing images in peripheral vision; and low spatial-frequency; but does suggest that that overall time taken to process information is slower than the Chronological age-matched group.

While the results of the present study have not been in support of the transient deficit hypothesis, this line of research should continue to be investigated as it may play an important part in literacy. In concluding, it is important to not lose sight of the reason for continuing the research in this area, which is of course to meet the needs of the children who experience SRD.

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APPENDIX A: CONSENT FORM FOR THE DEPARTMENT OF EDUCATION AND THE PARENTS

Central Queensland
UNIVERSITY

FACULTY OF ARTS
Department of Social Sciences

Dear Parent/s,

We are conducting research on the reading ability of students. This research is sponsored by the Central Queensland University.

We need your parental consent before participation may begin. We will be using computers to measure your child's visual processing. The programs used are fun and harmless. They are similar to other two dimensional computer games that your child may have already played. Your child will only be asked to press two marked buttons on the keyboard as their response to signals that appear on the screen.

In addition to visual processing, we will measure your child's vision acuity, intelligence, and reading ability. If you would like to know your child's performance, please feel free to ask us about the results when the testing is concluded. Alternatively, you may wish to indicate your preference by ticking the boxes on the following page.

Your child is under no obligation to participate as participation is totally voluntary. Your child is also free to stop participating at any stage, and at any time, within the research. Your child's individual results will only be available to the child and yourself. Also the identity of participants will be kept confidential when the research findings are published.

We believe this valuable research will advance knowledge in the field of reading ability. Our objective is to investigate the visual aspects involved in reading, and by this, we may be able to assist individuals who have problems in regard to reading.

Please fill and sign the attached form and ask your child to return it back to his/her teacher.

Yours Sincerely

Dr. G. A. Khiabani

Lecturer in Psychology

Bruce Highway North Rockhampton
Post: Rockhampton Qld 4702 Australia
Tel 079 30 9777 Fax 079 36 1361

Campuses located at Bundaberg Emerald
Gladstone Mackay Rockhampton

[ ] I hereby consent/do not consent that my child .... may participate in the reading ability study.

[ ] My child is also agreeable/not agreeable to participation.

[ ] I wish to obtain my child's performance results after completion of testing.

Please print your address if you would like to receive your child's performance result.

Your name: ....

Street number and street: ....

Suburb: .... Post Code: ....

Signature (Parent/guardian) .... Date ....

Department
of Education

Education House
30 Mary Street, Brisbane
Queensland, Australia

Refer to:
Telephone:

Our ref - 5/96

TO: PRINCIPALS

FROM: DIRECTOR, QUALITY ASSURANCE AND SCHOOL REVIEW

TOPIC: RESEARCH PROPOSAL BY DR AMIR KHIABANI

An application has been received by the department seeking approval to conduct research in a number of Queensland state schools. Details of the purpose and requirements of this research study are outlined in the attached statement.

Approval has been granted by the department for the applicant to approach you with a view to securing your cooperation in this project. As evidence of this approval, the applicant has been authorised to forward a copy of this memorandum to the principals of the schools listed on the attached statement. It should be noted, however, that although approval has been granted by the department, your school is under no obligation to participate in the study.

Should you have any queries relating to this study they may be directed to the researcher, or to me. I can be contacted on telephone (07) 237 0770.

Jan Gillies

JAN GILLIES
Director
Quality Assurance and School Review
Directorate

-1 FEB 1996

PO Box 33, Brisbane, Albert Street, Queensland 4002. Telephone (07) 3237 0770, Fax (07) 3237 0203.

RECORDS: 650/5
REF: 5/96

OUTLINE OF AN APPROVED RESEARCH STUDY IN QUEENSLAND STATE SCHOOLS

Title	*Effects of Colour, Size, Eccentricity, and Motion on Transient System Functioning of SRD Readers*		
Name of Applicant	Dr Amir Khiabani	**Telephone**	H: (079) 272 153 W (079) 309 204
Full-time Employment	Lecturer in Psychology		
Institution (through which study is undertaken)	Department of Social Sciences, Central Queensland University		
Aims of Study	• to examine the possibility that a transient visual system deficit might contribute to disabled readers' difficulty in letter and word recognition; • to study whether the perception of SRD readers is wholistic or analytic; • to examine the possible role of transient and sustained channels in the processing of whole and parts; • to investigate the utility of tinted lenses to improve the functioning of visual processing of reading/writing disabled students by compensating for a deficit in their visual transient system.		
Requirements of Study	• Three groups of 18 pupils will participate in this study: reading disabled, reading-age matched, and chronological-age matched normal readers. • Participants will be selected from local schools and be 8-11 years of age in the reading disabled group and chronological-age matched control group. • Pupils will be tested individually over a span of six sessions of thirty minutes each. • There will not be more than two sessions per day.		
Schools to be Approached	• Ten primary schools. • Not to disrupt the school program the number of pupils to be tested in each school will be limited to six. • Primary schools within the area local to Central Queensland University, Rockhampton.		
Conditions of Approval	1. All data to be treated as confidential. 2. Parental permission to be obtained for participating students. 3. Permission to be obtained from participating teachers. 4. Audiotapes and videotapes to be used only for the purposes of the research. 5. Students and teachers to be free to withdraw at any time. 6. Parents to be made fully aware of the requirements of the study at the time of signing. 7. The anonymity of participating students is preserved. 8. Parents are to be made fully aware of the purpose of the study, the planned mode of reporting, the nature of the contents of the data gathering instruments at the time of signing.		

....

1 FEB 1996

Department
of Education

Education House
30 Mary Street, Brisbane
Queensland, Australia

Refer to:
Telephone: Our ref: 5/96

-1 FEB 1996

Professor Geoff Lawrence
Department of Social Sciences
Central Queensland University
ROCKHAMPTON Q 4702

Dear Professor Lawrence

RE: RESEARCH PROPOSAL BY DR AMIR KHIABANI

A request was received from the above research applicant(s) who sought departmental approval to conduct a research study in Queensland state schools.

Approval is granted for the principals of selected state schools to be approached with a view to securing their cooperation in the proposed research project. The attached statement lists the schools selected, outlines briefly the nature and requirements of the study and specifies any conditions which we wish to impose.

The enclosed memorandum to principals has been sent to the applicant and should be provided to the principal of each school approached. However, it should be noted that, although approval has been granted by this department, the schools are under no obligation to participate in the study.

This approval is subject to the condition that, on completion of the study, the applicant forwards a copy of the research report to the department. This should be accompanied by a copy of an abstract and summary of the study where appropriate.

Should you have any queries relating to this study I can be contacted on telephone (07) 237 0770.

Yours sincerely

Jan Gillies

JAN GILLIES
Director
Quality Assurance and School Review
Directorate

APPENDIX B: SCORING SHEETS

SCHOOL:
YEAR:
NAME:

****** SUBJECT DATA *******

Expermient: Order of tests:

Identification: Teacher:

Condition:

SEX (1 Male, 2 Female):

D-O-B: / / 8
Date: / / 9 .

AGE at testing: Years Months Days

Handedness (1 Left, 2 Right):

TEST RESULTS:

* Neale Reading Analysis
Reading Age: years months

* WISC-R

Sub-tests	Raw score	Scaled Score
Information	________	________
Digit span	________	________
block Design	________	________
	________	________

* Vision Chart
ZAXNFD ____________________

* Vision Experiment 1.

Vision Experiment 2.

Vison Experiment 3.

Behavioural Observations:

APPENDIX C: ANSWER REACTION TIME MEANS AND STANDARD DEVIATIONS

EXPERIMENT 1: Global and Local Processing

Chronological age-matched group

	Eccentricity	Stimulus Level	
		Global	**Local**
Mean	0.5	633.58	882.97
S.D.		190.68	261.08
Mean	1.1	621.66	661.28
S.D.		216.89	178.64
Mean	2.4	616.92	640.29
S.D.		208.69	243.19
Mean	4.7	603.90	626.69
S.D.		190.58	217.85
Mean	7.2	597.97	604.08
S.D.		215.48	186.51
Mean	9.6	601.65	630.58
S.D.		173.35	209.08
Mean	12	621.33	638.39
S.D.		226.87	191.77
Mean	14.3	628.37	651.68
S.D.		206.49	221.20
Mean	16.3	634.81	665.54
S.D.		222.67	240.15

SRD group

	Eccentricity	Stimulus Level	
		Global	**Local**
Mean	0.5	719.47	951.04
S.D.		230.83	301.04
Mean	1.1	695.82	773.73
S.D.		257.57	250.00
Mean	2.4	687.03	724.40
S.D.		238.73	223.65
Mean	4.7	669.30	707.83
S.D.		228.13	247.20
Mean	7.2	676.99	701.00
S.D.		206.38	244.66
Mean	9.6	679.60	689.16
S.D.		239.13	212.93
Mean	12	692.11	718.05
S.D.		209.78	259.87
Mean	14.3	700.42	739.44
S.D.		195.46	253.35
Mean	16.3	706.89	748.44
S.D.		234.72	280.54

EXPERIMENT 1: Global and Local Processing

Reading age-matched group

	Eccentricity	Stimulus Level	
		Global	Local
Mean	0.5	797.58	1069.69
S.D.		198.75	303.64
Mean	1.1	775.93	874.20
S.D.		219.61	238.40
Mean	2.4	767.07	838.47
S.D.		201.44	209.90
Mean	4.7	756.44	804.66
S.D.		225.28	203.11
Mean	7.2	747.09	779.48
S.D.		199.84	196.26
Mean	9.6	757.28	797.32
S.D.		234.85	191.14
Mean	12	770.10	830.58
S.D.		211.48	159.90
Mean	14.3	775.92	855.16
S.D.		237.61	181.45
Mean	16.3	821.60	895.42
S.D.		260.20	228.64

EXPERIMENT 2: Eccentricity

Chronological age-matched group

	Eccentricity	Size			
		1.2	**0.6**	**0.3**	**0.15**
Mean	0	530.37	537.68	548.40	592.75
S.D.		121.79	130.62	114.04	154.03
Mean	1	544.83	550.43	566.91	600.76
S.D.		142.21	125.66	127.52	165.07
Mean	2	560.81	554.75	576.90	602.79
S.D.		146.91	131.32	153.21	175.33
Mean	3	572.33	561.13	602.67	615.09
S.D.		180.72	130.29	149.63	155.96
Mean	4	574.96	576.34	603.93	639.40
S.D.		151.27	144.93	154.16	171.75
Mean	5	588.22	586.38	611.33	664.67
S.D.		174.07	146.33	176.66	193.96
Mean	6	594.43	603.37	615.60	682.28
S.D.		181.95	147.64	159.73	182.66
Mean	7	606.72	619.79	624.58	738.10
S.D.		139.21	155.21	159.36	215.41
Mean	8	630.67	625.47	657.27	789.70
S.D.		210.26	201.64	184.09	262.94

EXPERIMENT 2: Eccentricity

SRD group

	Eccentricity	Size 1.2	0.6	0.3	0.15
Mean	0	716.16	745.55	740.20	746.84
S.D.		266.25	293.31	283.61	222.10
Mean	1	725.28	753.85	754.42	754.79
S.D.		273.92	282.79	274.76	257.11
Mean	2	734.18	759.82	773.48	777.30
S.D.		265.95	281.22	266.73	289.86
Mean	3	759.66	772.48	784.03	787.41
S.D.		295.17	291.94	291.61	260.03
Mean	4	763.41	790.53	797.61	832.54
S.D.		261.98	266.16	272.02	281.36
Mean	5	780.62	796.59	804.03	846.66
S.D.		308.84	302.01	287.63	293.51
Mean	6	797.67	805.21	812.07	880.26
S.D.		300.61	321.36	323.81	319.48
Mean	7	798.28	808.77	827.59	884.01
S.D.		305.23	316.86	312.34	307.44
Mean	8	824.66	815.16	825.53	911.20
S.D.		322.35	332.68	313.22	323.89

EXPERIMENT 2: Eccentricity

Reading age-matched group

	Eccentricity	Size			
		1.2	**0.6**	**0.3**	**0.15**
Mean	0	695.53	709.57	731.51	742.87
S.D.		195.31	198.25	221.42	209.74
Mean	1	737.76	751.52	781.73	804.91
S.D.		238.57	225.66	255.58	246.63
Mean	2	748.30	756.09	811.33	824.29
S.D.		222.10	251.23	250.69	239.92
Mean	3	768.92	767.63	822.05	837.31
S.D.		251.82	261.65	254.60	248.33
Mean	4	778.36	791.22	840.90	881.65
S.D.		229.15	254.95	267.73	285.14
Mean	5	782.66	823.10	840.89	900.55
S.D.		245.15	266.60	267.97	282.58
Mean	6	818.58	834.07	855.16	952.94
S.D.		267.56	272.32	274.24	313.23
Mean	7	846.51	843.65	903.17	977.53
S.D.		311.58	279.08	312.21	327.73
Mean	8	883.05	895.67	925.11	1012.10
S.D.		336.13	324.33	300.87	280.66

EXPERIMENT 3: Stimuli Size

Chronological age-matched group

	Eccentricity	Size	
		7.15	**2.36**
Mean	0.3	782.04	658.88
S.D.		242.86	203.99
Mean	0.6	670.96	616.35
S.D.		168.03	180.99
Mean	0.9	651.61	608.75
S.D.		191.78	155.65
Mean	1.2	639.39	603.27
S.D.		195.64	186.11
Mean	1.5	625.06	599.36
S.D.		189.40	175.43
Mean	1.8	620.09	595.03
S.D.		190.52	180.07
Mean	2.1	613.65	586.44
S.D.		166.65	170.87

EXPERIMENT 3: Stimuli Size

SRD group

	Eccentricity	Size	
		7.15	**2.36**
Mean	0.3	823.70	720.02
S.D.		279.70	224.47
Mean	0.6	725.71	690.43
S.D.		222.32	239.20
Mean	0.9	717.50	685.68
S.D.		215.05	220.62
Mean	1.2	711.46	681.46
S.D.		220.14	218.66
Mean	1.5	706.88	668.61
S.D.		244.81	223.49
Mean	1.8	695.94	666.90
S.D.		228.66	214.59
Mean	2.1	689.54	665.53
S.D.		243.33	221.85

EXPERIMENT 3: Stimuli Size

Reading age-matched group

	Eccentricity	Size	
		7.15	**2.36**
Mean	0.3	1054.93	870.87
S.D.		350.77	273.17
Mean	0.6	900.68	818.00
S.D.		284.60	263.91
Mean	0.9	871.10	803.90
S.D.		263.19	249.03
Mean	1.2	858.99	799.54
S.D.		271.91	272.74
Mean	1.5	833.89	785.07
S.D.		247.84	230.71
Mean	1.8	823.23	766.58
S.D.		235.46	231.46
Mean	2.1	813.96	776.24
S.D.		248.51	225.96

EXPERIMENT 4: Global and Local Interference Effects

Chronological age-matched group

Consistent

	Stimulus Level	Eccentricity					
		0.5	**1.1**	**2.4**	**4.7**	**7.2**	**9.6**
Mean	Global	635.85	589.36	577.31	580.41	554.47	589.10
S.D.		236.18	205.54	182.74	193.16	165.08	202.84
Mean	Local	838.51	737.30	713.22	674.98	667.78	681.68
S.D.		299.23	283.19	252.82	225.22	204.95	244.12

Inconsistent

Mean	Global	660.55	613.44	611.26	604.82	621.25	630.87
S.D.		251.25	210.11	208.65	200.09	240.07	222.36
Mean	Local	977.39	778.80	730.11	707.14	704.13	703.20
S.D.		324.06	216.80	211.84	229.93	224.66	218.93

Consistent		**12**	**14.3**	**16.3**
Mean	Global	591.76	591.51	608.53
S.D.		200.15	220.84	205.96
Mean	Local	715.77	756.85	834.92
S.D.		233.94	249.91	328.21

Inconsistent

Mean	Global	640.86	667.69	663.16
S.D.		215.90	215.70	220.75
Mean	Local	693.27	704.71	744.15
S.D.		202.48	222.51	302.10

EXPERIMENT 4: Global and Local Interference Effects

SRD group

Consistent

Stimulus Level Eccentricity

		0.5	**1.1**	**2.4**	**4.7**	**7.2**	**9.6**
Mean	Global	747.98	752.03	748.48	716.38	730.31	726.19
S.D.		254.43	321.94	289.93	255.45	285.49	286.03
Mean	Local	935.20	868.99	864.36	863.37	860.15	879.51
S.D.		328.12	289.43	306.93	259.65	317.73	308.30

Inconsistent

Stimulus Level

Mean	Global	807.65	781.74	762.55	758.88	776.83	807.98
S.D.		305.28	309.17	299.43	297.81	277.04	272.48
Mean	Local	1110.48	1000.21	945.50	916.03	838.53	846.77
S.D.		327.69	295.38	281.28	324.73	254.30	299.60

Consistent		**12**	**14.3**	**16.3**
Mean	Global	737.61	760.16	779.79
S.D.		283.81	317.23	298.72
Mean	Local	909.11	919.21	955.99
S.D.		332.04	312.82	331.47

Inconsistent				
Mean	Global			
S.D.		821.97	831.91	823.24
Mean	Local	277.79	308.73	272.95
S.D.		838.36	856.97	872.99
		273.12	263.17	299.22

EXPERIMENT 4: Global and Local Interference Effects

Reading age-matched group

Consistent

	Stimulus Level	Eccentricity 0.5	1.1	2.4	4.7	7.2	9.6
Mean	Global	858.94	842.85	826.52	808.99	821.88	812.01
S.D.		301.77	304.93	263.93	258.85	270.81	274.58
Mean	Local	1031.44	923.08	892.72	884.09	868.82	910.55
S.D.		337.93	293.70	276.81	271.83	263.50	277.77

Inconsistent

Mean	Global	939.78	926.65	913.01	881.25	844.94	909.90
S.D.		322.28	333.12	289.44	275.95	280.24	313.08
Mean	Local	1174.95	1035.41	1017.28	968.96	970.28	882.38
S.D.		350.11	307.82	297.81	291.17	304.47	274.67

Consistent		**12**	**14.3**	**16.3**
Mean	Global	849.02	858.33	864.78
S.D.		295.57	292.97	300.52
Mean	Local	947.79	997.25	1038.41
S.D.		324.10	327.54	364.50

Inconsistent

Mean	Global	925.42	934.00	957.34
S.D.		326.11	276.00	349.03
Mean	Local	893.03	866.54	924.62
S.D.		274.57	259.05	309.80

APPENDIX D: ANSWER ACCURACY MEANS AND STANDARD DEVIATIONS

EXPERIMENT 1: Global and Local Processing

	Chronological age-matched group				SRD group		
	Eccentricity	Stimulus Level			Eccentricity	Stimulus Level	
		Global	Local			Global	Local
Mean	0.5	0.99	0.77	Mean	0.5	0.98	0.75
S.D.		0.15	0.48	S.D.		0.24	0.51
Mean	1.1	0.98	0.95	Mean	1.1	0.94	0.9
S.D.		0.17	0.24	S.D.		0.29	0.4
Mean	2.4	0.97	0.95	Mean	2.4	0.97	0.93
S.D.		0.2	0.21	S.D.		0.26	0.3
Mean	4.7	0.98	1	Mean	4.7	0.98	0.95
S.D.		0.21	0.13	S.D.		0.23	0.29
Mean	7.2	0.99	0.98	Mean	7.2	0.97	0.95
S.D.		0.14	0.16	S.D.		0.26	0.28
Mean	9.6	0.97	0.98	Mean	9.6	0.92	0.95
S.D.		0.21	0.17	S.D.		0.29	0.28
Mean	12	0.98	0.97	Mean	12	0.95	0.94
S.D.		0.19	0.19	S.D.		0.28	0.28
Mean	14.3	1.01	1	Mean	14.3	0.96	0.95
S.D.		0.18	0.18	S.D.		0.19	0.3
Mean	16.3	1	0.95	Mean	16.3	0.94	0.94
S.D.		0.19	0.21	S.D.		0.34	0.27

EXPERIMENT 1: Global and Local Processing

Reading age-matched group

	Eccentricity	Stimulus Level	
		Global	Local
Mean	0.5	0.98	0.7
S.D.		0.26	0.56
Mean	1.1	0.95	0.92
S.D.		0.24	0.36
Mean	2.4	0.99	0.92
S.D.		0.17	0.28
Mean	4.7	0.97	0.95
S.D.		0.23	0.26
Mean	7.2	0.97	0.96
S.D.		0.23	0.28
Mean	9.6	0.97	0.96
S.D.		0.26	0.25
Mean	12	0.98	0.97
S.D.		0.2	0.2
Mean	14.3	0.97	0.98
S.D.		0.24	0.21
Mean	16.3	0.97	0.95
S.D.		0.23	0.32

EXPERIMENT 2: Eccentricity

Chronological age-matched group

	Eccentricity	Size			
		1.2	**0.6**	**0.3**	**0.15**
Mean	0	0.97	1	1	0.97
S.D.		0.17	0.09	0.15	0.2
Mean	1	0.99	0.98	0.98	0.96
S.D.		0.1	0.15	0.15	0.22
Mean	2	1	0.97	0.99	0.99
S.D.		0.12	0.18	0.12	0.18
Mean	3	0.97	0.97	0.97	0.95
S.D.		0.18	0.17	0.19	0.21
Mean	4	0.97	0.97	0.97	0.96
S.D.		0.16	0.18	0.18	0.2
Mean	5	0.95	0.97	0.99	0.95
S.D.		0.21	0.18	0.15	0.24
Mean	6	0.96	0.96	0.96	0.86
S.D.		0.19	0.2	0.21	0.36
Mean	7	0.99	0.99	0.99	0.83
S.D.		0.1	0.15	0.1	0.4
Mean	8	0.99	0.99	0.98	0.77
S.D.		0.14	0.18	0.15	0.47

EXPERIMENT 2: Eccentricity

SRD group

	Eccentricity	Size 1.2	0.6	0.3	0.15
Mean	0	0.95	0.95	0.99	0.92
S.D.		0.29	0.24	0.23	0.29
Mean	1	0.99	0.97	0.97	0.98
S.D.		0.2	0.26	0.23	0.27
Mean	2	0.97	0.98	0.99	0.96
S.D.		0.27	0.21	0.26	0.26
Mean	3	1.00	0.95	0.97	0.98
S.D.		0.24	0.29	0.27	0.25
Mean	4	0.95	0.98	0.97	0.92
S.D.		0.27	0.24	0.29	0.32
Mean	5	0.96	0.95	0.97	0.92
S.D.		0.27	0.31	0.26	0.38
Mean	6	0.93	0.98	0.91	0.87
S.D.		0.3	0.23	0.31	0.39
Mean	7	0.98	0.98	0.96	0.84
S.D.		0.28	0.31	0.38	0.49
Mean	8	0.94	0.97	0.92	0.81
S.D.		0.3	0.24	0.3	0.54

EXPERIMENT 2: Eccentricity

Reading age-matched group

	Eccentricity	Size 1.2	0.6	0.3	0.15
Mean	0	0.98	0.99	0.99	0.98
S.D.		0.15	0.19	0.12	0.17
Mean	1	0.99	1.01	1	0.98
S.D.		0.12	0.17	0.15	0.13
Mean	2	0.99	1	1.01	0.98
S.D.		0.14	0.15	0.14	0.18
Mean	3	1	0.99	0.99	0.99
S.D.		0.15	0.15	0.18	0.18
Mean	4	0.99	1.01	0.96	1.01
S.D.		0.15	0.15	0.22	0.18
Mean	5	0.97	0.99	1.01	0.95
S.D.		0.22	0.21	0.18	0.32
Mean	6	0.96	1	1.01	0.9
S.D.		0.21	0.22	0.13	0.34
Mean	7	1.01	1	0.97	0.86
S.D.		0.24	0.19	0.26	0.55
Mean	8	1	1	1.04	0.78
S.D.		0.3	0.3	0.31	0.61

EXPERIMENT 3: Stimuli Size

Chronological age-matched group

	Eccentricity	Size	
		7.15	**2.36**
Mean	0.3	0.81	1.01
S.D.		0.44	0.21
Mean	0.6	0.99	1
S.D.		0.16	0.17
Mean	0.9	0.99	0.99
S.D.		0.19	0.18
Mean	1.2	0.99	1.01
S.D.		0.2	0.22
Mean	1.5	1	0.99
S.D.		0.14	0.12
Mean	1.8	0.97	0.98
S.D.		0.18	0.22
Mean	2.1	0.98	0.99
S.D.		0.16	0.18

EXPERIMENT 3: Stimuli Size

SRD group

	Eccentricity	Size	
		7.15	**2.36**
Mean	0.3	0.8	0.94
S.D.		0.51	0.35
Mean	0.6	0.89	0.92
S.D.		0.36	0.29
Mean	0.9	0.91	0.89
S.D.		0.35	0.34
Mean	1.2	0.94	0.9
S.D.		0.33	0.32
Mean	1.5	0.96	0.91
S.D.		0.3	0.35
Mean	1.8	0.89	0.93
S.D.		0.35	0.33
Mean	2.1	0.91	0.95
S.D.		0.32	0.32

EXPERIMENT 3: Stimuli Size

Reading age-matched group

	Eccentricity	Size	
		7.15	**2.36**
Mean	0.3	0.82	0.94
S.D.		0.66	0.32
Mean	0.6	0.91	0.95
S.D.		0.39	0.32
Mean	0.9	0.96	0.94
S.D.		0.29	0.33
Mean	1.2	0.91	0.94
S.D.		0.32	0.28
Mean	1.5	0.93	0.93
S.D.		0.3	0.28
Mean	1.8	0.96	0.92
S.D.		0.27	0.29
Mean	2.1	0.95	0.94
S.D.		0.26	0.28

EXPERIMENT 4: Global and Local Interference Effects

Chronological age-matched group

Consistent

	Stimulus Level	Eccentricity 0.5	1.1	2.4	4.7	7.2	9.6
Mean	Global	0.99	0.98	0.98	0.99	1	1
S.D.		0.13	0.22	0.17	0.14	0.15	0.13
Mean	Local	0.9	1	0.96	0.97	0.96	0.97
S.D.		0.39	0.23	0.23	0.19	0.23	0.18
Inconsistent							
Mean	Global	1	1	0.98	0.98	0.96	0.95
S.D.		0.1	0.15	0.15	0.21	0.23	0.23
Mean	Local	0.61	0.85	0.94	0.98	0.99	0.97
S.D.		0.52	0.38	0.24	0.16	0.19	0.2

Consistent		**12**	**14.3**	**16.3**
Mean	Global	0.97	1	1
S.D.		0.17	0.1	0.18
Mean	Local	0.98	0.99	0.83
S.D.		0.19	0.15	0.44
Inconsistent				
Mean	Global	0.99	0.98	0.95
S.D.		0.17	0.18	0.23
Mean	Local	0.99	1	1
S.D.		0.14	0.15	0.12

EXPERIMENT 4: Global and Local Interference Effects

SRD group

Consistent

Stimulus Level Eccentricity

		0.5	**1.1**	**2.4**	**4.7**	**7.2**	**9.6**
Mean	Global	0.96	0.94	0.97	0.92	0.98	0.98
S.D.		0.26	0.3	0.25	0.29	0.18	0.23
Mean	Local	0.91	0.92	0.93	0.89	0.93	0.9
S.D.		0.46	0.34	0.32	0.35	0.3	0.37
Inconsistent							
Mean	Global	0.94	0.93	0.94	0.94	0.91	0.92
S.D.		0.32	0.29	0.26	0.29	0.34	0.35
Mean	Local	0.42	0.69	0.78	0.89	0.9	0.92
S.D.		0.55	0.49	0.45	0.44	0.34	0.32

Consistent		**12**	**14.3**	**16.3**
Mean	Global	0.99	0.98	0.99
S.D.		0.27	0.26	0.28
Mean	Local	0.91	0.93	0.71
S.D.		0.32	0.29	0.53
Inconsistent				
Mean	Global	0.85	0.87	0.88
S.D.		0.38	0.38	0.4
Mean	Local	0.98	1	0.97
S.D.		0.28	0.26	0.30

EXPERIMENT 4: Global and Local Interference Effects

Reading age-matched group

Consistent

	Stimulus Level	Eccentricity 0.5	1.1	2.4	4.7	7.2	9.6
Mean	Global	1.03	0.99	0.97	0.99	0.99	1
S.D.		0.35	0.22	0.2	0.14	0.17	0.12
Mean	Local	1.08	0.96	1	0.98	1	0.94
S.D.		0.45	0.28	0.2	0.19	0.14	0.27

Inconsistent

		0.5	1.1	2.4	4.7	7.2	9.6
Mean	Global	1.04	0.97	0.96	0.94	0.96	0.98
S.D.		0.34	0.24	0.26	0.26	0.22	0.2
Mean	Local	0.73	0.8	0.84	0.93	0.88	0.96
S.D.		0.74	0.48	0.42	0.29	0.34	0.25

Consistent

		12	14.3	16.3
Mean	Global	0.98	0.97	1.00
S.D.		0.16	0.16	0.26
Mean	Local	0.95	0.93	0.89
S.D.		0.29	0.29	0.36

Inconsistent

		12	14.3	16.3
Mean	Global	0.94	0.96	0.98
S.D.		0.29	0.21	0.24
Mean	Local	0.98	0.98	0.90
S.D.		0.21	0.19	0.33

APPENDIX E: SUMMARY TABLES OF ANALYSIS OF VARIANCE FOR REACTION TIME

Experiment 1: Global and Local Processing

Source of Variation	SS	DF	MS	F	P
Within + Residual	12574442.89	52	241816.21		
Group	5840714.46	2	2920357.2	12.08	.000

Source of Variation	SS	DF	MS	F	P
Within + Residual	612731.21	52	11783.29		
Target Level	923714.64	1	923714.64	78.39	.000
Target Level by Group	77684.69	2	38842.35	3.30	.045

Source of Variation	SS	DF	MS	F	P
Within + Residual	1966226.46	416	4726.51		
Eccentricity	2053604.76	8	256700.59	54.31	.000
Eccentricity by Group	58044.06	16	3627.75	.77	.723
Within + Residual	1741969.43	416	4187.43		
Eccentricity by Target level	1187422.69	8	148427.84	35.45	.000
Eccentricity by Target level by Group	31849.03	16	1990.56	.48	.958

Experiment 2: Eccentricity

Source of Variation	SS	DF	MS	F	P
Within + Residual	40569646.00	52	780185.50		
Group	21045749.19	2	10522875	13.49	.000

Source of Variation	SS	DF	MS	F	P
Within + Residual	3180051.82	156	20384.95		
Size	1723544.94	3	574514.98	28.18	.000
Size by Group	142758.25	6	23793.04	1.17	.327

Source of Variation	SS	DF	MS	F	P
Within + Residual	4044430.96	416	9722.19		
Eccentricity	3944666.99	8	493083.37	50.72	.000
Eccentricity by Group	245209.95	16	15325.62	1.58	.072
Within + Residual	5423272.86	1248	4345.57		
Eccentricity by Group by Size	111342.71	48	2319.64	0.53	.996
Eccentricity by Size	373523.43	24	15563.48	3.58	.000

Experiment 3: Stimuli Size

Source of Variation	SS	DF	MS	F	P
Within + Residual	9121908.87	53	172111.49		
Group	6100090.20	2	3050045.1	17.72	.000

Source of Variation	SS	DF	MS	F	P
Within + Residual	408253.32	53	7702.89		
Eccentricity	589074.54	1	589074.54	76.47	.000
Eccentricity by Group	48782.80	2	24391.40	3.17	.050

Source of Variation	SS	DF	MS	F	P
Within + Residual	1103648.17	318	3470.59		
Eccentricity by Group by Size	25429.91	12	2119.16	.61	.833
Eccentricity by Size	247363.93	6	41227.32	11.88	.000

Source of Variation	SS	DF	MS	F	P
Within + Residual	1220921.76	318	3839.38		
Size	1429303.51	6	238217.25	62.05	.000
Size by Group	129636.41	12	10803.03	2.81	.001

Experiment 4: Global and Local Interference Effect

Source of Variation	SS	DF	MS	F	P
Within + Residual	2081440878	51	93104.35		
Group	205713048.2	2	102856524	1104.74	.000
Target level	52297196.54	1	52297197	561.71	.000
Target level by Group	3442702.04	2	1721351.0	18.49	.000
Target level by Eccentricity	2412881.80	8	301610.23	3.24	.001
Target level by Eccentricity by Group	1429972.18	16	89373.26	.96	.499
Target level by Eccentricity by Consistency	6450607.62	8	806325.95	8.66	.000
Target level by Consistency	5165871.66	1	5165871.7	55.48	.000
Target level by Consistency by Group	145185.24	2	72592.62	.78	.459
Target level by Consistency by Eccentricity by Group	1753097.18	16	109568.57	1.18	.278

Source of Variation	SS	DF	MS	F	P
Eccentricity	8507835.86	8	1063479.5	11.42	.000
Eccentricity by Group	5473444.96	16	342090.31	3.67	.000
Eccentricity by Group by Consistency	1188383.84	16	74273.99	.80	.690
Eccentricity by Consistency	2475731.22	8	309466.40	3.32	.001

Source of Variation	SS	DF	MS	F	P
Consistency	4322850.96	1	4322851.0	46.43	.000
Consistency by Group	1176473.56	2	588236.78	6.32	.002

APPENDIX F: SUMMARY TABLES OF ANALYSIS OF VARIANCE FOR ACCURACY

Experiment 1: Global and Local Processing

Source of Variation	SS	DF	MS	F	P
Within + Residual	1064.66	14796	.07		
Group	2.33	2	1.17	16.22	.000
Target level	6.64	1	6.64	92.30	.000
Target level by Group	.21	2	.11	1.48	.229
Target level by Group by Eccentricity	.66	16	.04	.57	.908

Source of Variation	SS	DF	MS	F	P
Eccentricity	15.88	8	1.99	27.59	.000
Eccentricity by Group	.86	16	.05	.75	.747
Eccentricity by Target Level	18.84	8	2.35	32.72	.000

Experiment 2: Eccentricity

Source of Variation	SS	DF	MS	F	P
Within + Residual	4734.31	23651	.20		
Group	24.64	2	12.32	61.54	.000
Eccentricity	76.43	8	9.55	47.73	.000
Eccentricity by Group	11.16	16	.70	3.48	.000

Source of Variation	SS	DF	MS	F	P
Size	100.39	3	33.46	167.17	.000
Size by Group	2.69	6	.45	2.24	.037
Size by Eccentricity	126.75	24	5.28	26.38	.000
Size by Eccentricity by Group	11.45	48	.24	1.19	.171

Experiment 3: Stimuli Size

Source of Variation	SS	DF	MS	F	P
Within + Residual	1120.74	11718	.10		
Group	9.11	2	4.55	47.60	.000
Eccentricity	1.60	1	1.60	16.76	.00
Eccentricity by Group	.76	2	.38	3.95	.019
Eccentricity by Size by Group	1.08	12	.09	.94	.507

Source of Variation	SS	DF	MS	F	P
Size	5.36	6	.89	9.33	.000
Size by Group	1.17	12	.10	1.02	.428
Size by Eccentricity	.99	6	.16	1.72	.111

Experiment 4: Global and Local Interference Effect

Source of Variation	SS	DF	MS	F	P
Within + Residual	1898.21	22356	.08		
Group	14.05	2	7.03	82.76	.000
Target level	18.89	1	18.89	222.46	.000
Target level by Group	.73	2	.37	4.31	.014
Target level by Eccentricity	28.02	8	3.50	41.25	.000
Target level by Eccentricity by Group	2.80	16	.18	2.06	.007
Target level by Eccentricity by Consistency by Group	5.58	16	.35	4.11	.000
Target level by Consistency	.68	1	.68	7.97	.005
Target level by Consistency by Group	1.01	2	.51	5.97	.003
Target level by Consistency by Eccentricity	38.95	8	4.87	57.35	.000

Source of Variation	SS	DF	MS	F	P
Eccentricity	14.28	8	1.78	21.02	.000
Eccentricity by Group	7.06	16	.44	5.19	.000
Eccentricity by Consistency	22.17	8	2.77	32.63	.000
Eccentricity by Consistency by Group	2.96	16	.19	2.18	.004

Source of Variation	SS	DF	MS	F	P
Consistency	11.60	1	11.60	136.66	.000
Consistency by Group	2.00	2	1.00	11.80	.000