EYE TRACKING IN CHILDREN WITH ADHD: EXPLORING NEW DIAGNOSTIC MEASURES AND READING TRAINING PROCEDURES

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Social Sciences
at the
University of Waikato
by

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University of Waikato
1999

ABSTRACT

The overall aim of this research was to explore new diagnostic measures and reading training procedures for children with Attention Deficit Hyperactivity Disorder (ADHD). Specifically, it was hypothesised that the participants with ADHD would have different eye movement behaviours when reading aloud and silently compared to matched controls. It was also hypothesised that there would be a relationship between their eye movement behaviours and their leg and arm movements, with the administration of methylphenidate producing noticeable changes. The participants consisted of three male children with ADHD, aged between 7-8 years, and two reading level and age matched controls. The research consisted of two experiments during which the participants read short stories, while ignoring two visual distracters. The eye tracker recorded their eye lines of gaze, including their the number of fixations and the angles of saccades. During the training procedure, visual reminders prompted the participants to focus their attention on the reading task. As additional help, the computer-generated words were highlighted on the desired reading position. A calibration procedure that accommodated the hyperactivity of the participants with ADHD was successfully designed and outlined. Preliminary results indicate that the eye movements of the participants with ADHD differed from that of their matched controls and were characterised by rapidly changing lines of gaze and shorter fixation periods, which tended to be more pronounced when reading silently. MPH reduced the amount of arm and leg movements but did not reduce the rapidly changing eye movements of one participant with ADHD, compared to matched controls with and without ADHD. The visual prompts in the training procedure had little social validity, but highlighting the text resulted in an increased consistency in the eye movement variables and reading performance when reading aloud and silently for both the participants with and without ADHD.

Acknowledgments

I would like to extend a warm and heart felt thank you to Jill, Les and Kieran for all of their help and support throughout my university career. Your support and love have has meant the world to me. I would also like to thank Dr Russ Falconer for firmly believing that I had every right to study and providing his extensive and top quality medical expertise to help me achieve this dream.

I would like to thank Dr Robert Isler for his support and guidance, that exceeded any of my expectations. If my experience is anything to go by, you CAN change the world of education Robert! I would also like to thank Ross Oliver for all of his time, technical knowledge and computer wizardry. Thank you Lisa, the bestest research assistant in the world, to whom I will always be grateful. I would also like to thank Johnathan for listening to my many lofty education ideals and for giving up his weekends to help with this research.

I would like to thank "Max," "John," "Andrew," "Jason," " Mike" and their families for their participation and interest in this research. I wish you all the best for the future! I would like to thank one young boy in particular, for teaching me that having ADHD does not mean that you can not think or have the ability to change, but that you have limitations that we, as clinicians, need to identify and understand. I will never forget your wise words, "Yeah, Kirsty, it has been heaps better since I've gotten help from the psychologist, I don't get into as much trouble and people like me. But to be honest, sometimes, I still just want to crash my bike." You summed up the process of change eloquently and with insight that exceeded your years. I dedicate this thesis to all the young people with ADHD and wish you all the luck in the world with the many bikes you may want to crash in the future!

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1. INTRODUCTION

The various aspects of visual attention have been explored in detail by researchers in the fields of human experimental and developmental psychology for a number of years. The advances in knowledge and experimental techniques are rarely discussed or explored by clinicians, researchers or educators in the field of Attention Deficit Hyperactivity Disorder (ADHD). This is unfortunate, because the fundamental deficit of this disorder is attention and it is not fully or objectively defined, or assessed. Thus, the overall aim of this research was to explore how eye tracker technology, a principle research tool in visual attention, can help examine the deficit in attention as it is discussed in reference to ADHD. The challenge was to combine the knowledge available in these two fields and design potential diagnostic measures and training procedures that reflected how children with ADHD pay attention when reading. The following is a literature review of the research that formed the backbone of the current research.

1.1 Attention Deficit Hyperactivity Disorder

ADHD is characterised by persistent age-inappropriate inattention, impulsivity and overactivity (Nigg, Swanson & Hinshaw, 1997). The core symptoms often result in significant family, peer and achievement difficulties that subsequently put the children at risk of poor social and achievement outcomes (Schachar, Logan, Wachsmuth & Chajczyk, 1988).

ADHD remains one of the most controversial conditions in terms of its diagnosis and treatment. There have been a number of changes in thinking concerning the role of the brain in ADHD over the years. For example in the 1940's and 1950's symptoms, now associated with ADHD, were thought to be a result of brain damage due to encephalitis (Wolraich & Baumgaertel, 1997). In the 1960's it was known as minimal brain damage or dysfunction, however this conceptualisation changed when researchers could not provide objective evidence of brain dysfunction (Wolraich & Baumgaertel, 1997). Subsequently, the definition changed to a focus on the more behavioural descriptive label of hyperkinetic reaction of childhood or hyperactive child syndrome. In the early

1980's it was referred to as Attention Deficit Disorder (ADD) and in 1987 was referred to as ADHD, but the most recent criteria, outlined in the Diagnostic and Statistical Manual of Psychiatric Disorders - Fourth Edition [DSM-IV (American Psychiatric Association, 1994) differentiates between ADD and ADHD. This manual differentiates ADHD into two dimensions, hyperactivity and impulsivity, with three subtypes, the predominantly inattentive type, predominantly hyperactive/impulsive type and the combined type where children meet the criteria on both dimensions. The DSM-IV criteria specify that the age of onset is before 7 years of age and the associated symptoms are present for a minimum of six months and observable in two or more settings of which there is evidence of significant clinical impairment in social, academic or occupational functioning. However, Solanto, Wender and Bartell (1997) note that there remains a lack of information on the core symptoms of the disorder, particularly in terms of inattentiveness. Mannuzza, Klein, Bessler, Malloy and Hynes (1997) state that research often uses the terms "hyperactive," Attention Deficit Disorder and ADHD interchangeably which can lead to confusion. However, consistent with the current trend, this research will refer to ADHD only within the criteria outlined by the American Psychiatric Association (1994).

ADHD is one of the most prevalent and studied disorders and is conservatively estimated to occur in 3% to 6% of the population (Tannock, 1998) and has been identified in every nation and culture studied (Barkley, 1998). However, there is little research conducted that explores differences in symptomology, or the effectiveness of assessment procedures and interventions, in terms of cultural differences world wide (Reid, 1995). Within the New Zealand context there is no current research available on differences in presentation and intervention outcome between Maori and non-Maori. ADHD is over-represented in boys by approximately 3:1 and little is known about any differences in ADHD between males and females in terms of symptomology and intervention effectiveness (Arnold, 1996). Therefore, given the exploratory nature of the current research and the potential for gender differences in eye movement behaviour, only male participants were selected.

ADHD is usually diagnosed by paediatricians and clinical psychologists who follow several principles and procedures in an attempt to ensure that the best diagnostic decision is reached. These procedures generally involve evaluating the child directly through observations and psychoeducational tests (Purvis & Tannock, 1997), and gathering data from a variety of sources that include teachers and parents, as the symptoms of ADHD are not always obvious in all situations (Wolraich & Baumgaertel, 1997). Rating scales provide a time and cost effective method of obtaining information about a range of behaviours and provide a normative basis for comparison (Wolraich & Baumgaertel, 1997). The Conners' Teacher Rating Scale-Revised (CRTS-R) and the Conners' Parent Rating Scale-Revised (CPRS-R) are two of the most frequently used scales in research on ADHD (Lufi, Parish-Plass & Gai, 1997; Solanto, Wender & Bartell, 1997; Whitmont & Clark, 1996). The 14 subscales reflect symptoms associated with ADHD according to the criteria outlined in DSM-IV (American Psychiatric Association, 1994). For screening purposes the Conners' manual states that the ADHD Index, the Conners' Global Index and the DSM-IV: Total, are particularly useful (Conners, 1997). However, there is increasing evidence that these sources may not be accurate or objective and must always be corroberated by a full clinical investigation (Teicher et al., 1996). Therefore, the diagnosis of ADHD remains dependent on specific, observed behaviours, with no other alternative specific diagnostic measures available, despite recent research demonstrating differential brain activity and support for a genetic component (Wolraich & Baumgaertel, 1997).

One of the difficulties in diagnosing ADHD is that it is often associated with a number of comorbid psychiatric disorders, with 80% co-diagnosed with behavioural disorders or learning disabilities (Mathes & Bender, 1997). There tends to be a high comorbidity between ADHD and oppositional defiant disorder, conduct disorder, anxiety or mood disorders and language and communication disorders (Wolraich & Baumgaertel, 1997). Depression and anxiety can affect attention and therefore must be ruled out when ADHD is suspected (Wolraich & Baumgaertel, 1997). Barkley (1990) estimated that over 50% of children with ADHD will have obvious differences in motor movement and a large number will have comorbid motor problems.

The course of the developmental change over time in children with ADHD is not clear and little is known about what happens to them in adulthood. Hart et al. (1995) found that for 106 boys with ADHD, symptoms of hyperactivity-impulsivity decreased over a four year period, independently of any pharmacological or inpatient treatment, but inattention symptoms did not, rather they declined only in the first year. Hart et al. concluded that this highlights the need for more specific and hence more effective treatment for ADHD, particularly in the area of attention. Mannuzza et al. (1997) found in a follow-up study of 85 boys with ADHD and 73 controls, that the individuals with ADHD completed significantly less formal schooling than the controls, and had lower-ranking occupational positions which were not accounted for by mental or intellectual status. Mannuzza et al. concluded that ADHD can predispose disadvantages in terms of schooling and occupational achievements. Therefore developing effective treatments for children with ADHD is vital so that the level of impairment can be lessened during the first critical years of education.

The aetiology of ADHD is not well understood, but the potential role of neuro-psychological or neurobiological deficits are an important consideration in current theories (Nigg et al., 1997). These theories tend to highlight the role of the frontal cortex, especially the orbitofrontal, premotor and prefrontal areas, and subcortical structures (Nigg et al., 1997). Advances in technological abilities have contributed to the substantial progress in ADHD research in the 1990's. Neuroimaging techniques have implicated frontospatial pathways and provided preliminary evidence for brain anomalies being associated with the observed cognitive impairments (Tannock, 1998). One of the main techniques used is Positron Emission Tomography (PET) scanning where radioactive substances are used to produce an image that reflects the level of metabolism of cells (Matochik et al., 1993). Using this technique, Lou, Henriksen, Bruhn, Borner and Nielsen (1989) found that through regional blood flow comparisons of dysphasic, ADHD, and control children, the children with ADHD showed decreased metabolic activity in the frontal lobes and basal ganglia and had an increased metabolic activity in the primary sensory and sensorimotor regions. Costellanos et al. (1996) demonstrated the presence of a dysfunction in the right-sided prefrontal-striatal systems by using anatomic brain magnetic resonance imaging for 57 boys with ADHD and 55 matched controls. Specifically, Costellanos et al. found that the participants with ADHD had a 4.7% smaller total cerebral volume, with a significant loss of normal right > left asymmetry in the caudate and a reversal of the normal lateral ventricular asymmetry compared to the control group. They also found that the children with ADHD had smaller right frontal regions, globus pallidus and cerebellum. Ross, Hommer, Breiger, Varley and Radant (1994), using a delayed response task, found that children with ADHD had deficits in inhibiting their responses but they did not observe differences in the preparation of motor response, or the accuracy of the visio-spatial memory between the two groups. They proposed that this deficit may be related to biological impairment located outside the dorsolateral prefrontal cortex. Therefore there is accumulating evidence that there are significant differences in the brain structures of children with ADHD. Barkley (1998) highlights that these areas are the very ones that are thought to regulate attention. For example, the prefrontal cortex is involved in resisting distractions. Barkley (1997) holds that the capacity to maintain one's performance toward a task despite distraction may be an indicator of interference control. Current advances in genetic research implicates familiarity and heredity factors as siblings of children with ADHD are five to seven times more likely to develop ADHD and children whose parents have ADHD have up to 50 percent chance of developing ADHD (Barkley, 1998). Attempts to isolate the defective genes are currently underway (Barkley, 1998).

Carte et al. (1996) state that a significant disadvantage in the current diagnostic practices of ADHD is that even though most believe that ADHD has a neurobiological basis none of the accepted diagnostic instruments specifically assess attention. Children with ADHD have particular difficulty in sustaining attention which involves being able to remain vigilant over a period of time (Schachar et al., 1988). The ability to sustain attention has frequently been investigated using different versions of the Continuous Performance Task (CPT) where the participants respond to a specific target letter or pattern of letters within a series of non target letters (Schachar et al., 1988). However, Schachar et al. (1988) did not find that children with ADHD have a unique sustained attention deficit when compared to children with conduct disorder, mixed conduct disorder and ADHD, emotional disorder, learning disorder and the control group. They used three versions of the CPT and found that the performance of all the participants deteriorated as the time on the task increased (sustained attention) and improved when the participants were given the opportunity to prepare attention.

Barkley (1998) holds that current research is beginning to suggest that ADHD is not a disorder of attention but rather arises as a developmental failure in the areas of the brain related to inhibition and self control. Indeed, in a review of a number of studies, Tannock (1998) concluded that cognitive research has implicated the role of response inhibition. Grainger (1997) conducted another review recently and found that none have been able to isolate deficits in sustained attention, divided and focused attention, overall attention capacity or controlled automatic processing. Alternatively, Grainger holds that the evidence suggests there are problems in the higher level functions such as self-regulation and inhibitory control. In children without ADHD their executive processes determine how they control and focus attention which in turn helps them filter extraneous background noise, allowing them to execute and maintain control over task performance (Grainger, 1997). However, for the children with ADHD the ability to control their attention is slower, more variable and more inaccurate in tasks in which attention is a major factor. Thus Grainger (1997) holds that the executive processes responsible for the organisation and monitoring of information processing, the deployment of attention and effort, both sustained and repeated, that involves inhibition of inappropriate responses, appear to be implicated in the deficits observed in children with ADHD. Barkley (1997) proposed a theoretical model of self-control and ADHD that links the behavioural inhibition observed in ADHD with impairments to four executive neuropsychological functions, the working memory, self-regulation of affect-motivation-arousal, internalization of speech and reconstitution that involves behavioural analysis and synthesis.

There have been a number of attempts to develop objective measures to demonstrate hyperactivity and to quantify impairments in attention or impulse control (Teicher et al., 1996). Porrino et al. (1983) were the first to demonstrate that children with ADHD had higher activity levels, between 25% to 30%, than age-matched controls during all hours they were awake and asleep. Porrino et al. observed that these differences were particularly obvious during academic classroom activities. Indeed, there is increasing evidence that the assessment of motoric activity during CPT may be an effective method for quantifying hyperactivity in individuals with ADHD (Teicher, Ito, Glod & Barber, 1996). These authors recorded the head movements of 18 boys with ADHD and 11 normal controls using an infrared analysis system whilst they undertook a CPT. They found that the participants with ADHD moved their heads 2.3 times more when compared to the controls ($p < .05$), and 3.4 times as far ($p < .05$), and covered a 3.8 fold greater area ($p < .001$) and had a more linear and less complex pattern of movement ($p < .001$). The participants with ADHD responded more slowly and with considerably more variability and the complexity of their head movements and the variability in the response latency to the CPT was significantly correlated with teacher ratings. They concluded that hyperactivity in ADHD can be objectively and reliably discerned in the frequency, amplitude and pattern of body movements.

Caplan, Guthrie and Komo (1996) provide evidence that there may be a biological correlate of certain aspects of the biochemical and arousal/attention dysfunction in children with ADHD. These authors investigated the spontaneous blink rate of 28 children with ADHD and 47 controls during a listening, a conversation and a verbal recall task. They found that there was a significant increase in the blink rate across the three tasks for the controls, but not for the children with ADHD. Caplan et al. also found that the participants with ADHD taking stimulants had a significantly higher blink rate than the controls during the listening task. Therefore the children with ADHD do not modulate their rate of blinking across different cognitive tasks.

1.2 Interventions for ADHD

It is clear that children with ADHD are at high risk of scholastic and social failure in school settings (DuPaul, Eckert & McGoey, 1997). Therefore it is important that effective strategies for managing and enhancing academic performance are developed. Recent research suggests that a long-term multimodal treatment approach has the best chance of reducing the problems associated with ADHD (Grainger, 1997).

1.2.1 Stimulant medication

There are a number of stimulant medications shown to be effective in reducing a number of the symptoms of ADHD. The most frequently prescribed stimulant medication used to treat ADHD is Methylphenidate (MPH) which is commonly referred to as Ritalin. MPH is a short-acting medication that begins to work after 20-40 minutes, with the maximum effectiveness occurring within 1-1.5 hours and wearing off after approximately four hours (Irwin, 1996). Generally, MPH is given at breakfast and lunch time, but because it is a short acting medication the recipient's behaviour across the day is characterised by fluctuations in the symptoms of hyperactivity and impulsivity (Irwin, 1996). The exact neurochemical mechanism of MPH is not currently understood (Irwin, 1996). Previously it was believed that MPH had a paradoxical effect on children with ADHD in that it would "calm" the hyperactive child and stimulate children without ADHD (Wolraich & Baumgaertel, 1997). However, this has been disputed as stimulants have been proven to increase alertness and on-task behaviour, and to decrease impulsivity and distractibility, in both children and adults with and without ADHD (Irwin, 1996).

There has been an increasing amount of research, media attention and public concern relating to the use, and suspected over prescription of stimulant medication in treatment of ADHD (Perring, 1997). Estimates of the number of children with ADHD taking MPH vary between 80% (Perring, 1997) to 90% (Wolraich & Baumgaertel, 1997). Levy (1997) states that the public concern about the overuse of medications has alternated with increasing parental demands for treatment of ADHD.

There has been a considerable amount of research that demonstrates the short term improvements in the symptoms of ADHD with MPH. Safer et al (1996) estimate, from a number of comprehensive studies, that at least 75% of youths with ADHD exhibit a noticeable lessening of behavioural and attention difficulties after stimulant medication. MPH has also been shown to improve the recipient's ability to modulate motor behaviour (Whitmont & Clark, 1996), improve self-regulation and increase concentration or effort spent on tasks (Swanson et al., 1993), improve classroom behaviour and academic productivity and output (Grainger, 1997). It is also believed to bring about an improvement in the associated features of ADHD, such as in deportment, level of aggression and social interactions (Swanson et al., 1993). However, after conducting a synthesis of the review literature on stimulant use with children with ADHD, Swanson et al., (1993) did not find that they facilitate an improvement in reading, athletics or positive social skills. Indeed, it has been estimated that approximately 10-20% of children do not respond sufficiently to stimulant medication and require additional assistance to function successfully in the classroom (Mathes & Bender, 1997). Of those that respond favourably, only a small number of children's behaviour improves to fall within the normal range and thus most require additional types of interventions (Mathes & Bender, 1997).

It is important the benefits of MPH are considered and weighed against the side effects for each individual case. The short-term side effects of MPH occur frequently, but generally subside after 1-2 weeks, however in approximately 5% the side effects warrant the termination of use (Efron, Jarman & Barker, 1997). These side effects include decreased appetite, mild stomach upset, some weight loss, headaches, anxiousness, proneness to crying and sleep disturbance (Long & Rybacki, 1995; Efron et al., 1997). Long-term side effects include decreased growth, tics, and in approximately 2% of long-term users gradual emergence of paranoia has been observed (Swanson et al., 1993). There is a dearth of research on the long- term effects of MPH on academic achievement. Levy (1997) holds that if prescribed properly and the children monitored carefully the side effects are not a major concern. Interestingly, in a double-blind study comparing the side effects of MPH and Dexamphetamine in children with ADHD, Efron et al. (1997) found that many of the symptoms commonly attributed to these medications are actually pre-existing characteristics of the children and improved with stimulant medication. Seidman et al. (1997) state that research into the effects of stimulant drugs is important given the high number of individuals who receive this treatment and will provide much needed information for clinicians and educators.

Children with ADHD have been found to perform at a lower level than their typical peers in a wide range of attention tasks, however these deficits have been observed to be improved by the use of MPH (Jonkman et al., 1997). For example, Rapport and Kelly (1997) found that the reaction times to target stimuli improved on various attention tasks such as CPTs after the administration of MPH whilst reducing the number of omission and commission errors. Event-related potentials (ERPs) have been used to investigate the effects of MPH on the underlying attention processes and performance in children with ADHD. Jonkman et al., (1997) investigated the extent that MPH ameliorated the performance and event-related potential (ERP) deficits identified in an earlier study of the same group of children with ADHD, using auditory and visual selective attention tasks. They used a double-blind placebo controlled study and presented 18 children with ADHD with both auditory and visual attention tasks comprised of frequent (90%) and infrequent (10%) stimuli in both relevant and irrelevant input channels. Jonkman et al. (1997) found that administering 15 mg of MPH had a significant effect on the correct detections for the visually attended task and not for the auditory task. During the visual task MPH increased the percentage of hits, caused higher central, occipital and parietal ERP amplitudes to attended stimuli, as well as enhancing the frontal processing negativity. They concluded that MPH improves some of the visual and auditory deficits detected in the ADHD children from the previous experiment but not all.

Lufi et al. (1997) state that, given the prevalent use of MPH to treat ADHD, further research is necessary to demonstrate that MPH does improve the behaviour and cognitive/learning functioning. In a double-blind, cross-over, placebo-control design study, Lufi et al. (1997) investigated the effect of MPH on the cognitive and personality functioning of 20 Israeli children with ADHD. They did not find any significant differences on measures of cognitive ability or personality measures when comparing the MPH and placebo treatment periods for each participant. However, they did find that on the CTRS there was a significant improvement in the participants' behaviour both during the MPH and placebo treatment periods. Although no cognitive differences were found, teachers rated the children's ability to learn as better under the MPH condition as opposed to the control and placebo periods. Lufi et al. suggest that these results indicate that the most prominent effect of MPH is an improvement in behaviour but not in cognitive functioning or personality characteristics in the classroom. Indeed, Solanto et al. (1997) found that MPH reduced task-irrelevant and disinhibited behaviours, such as restlessness in seat. They concluded that these behaviours occur to promote an optimal state of arousal and enhance cognitive performance but MPH replaced the need for these self-activating behaviours and that MPH is therefore involved in sustaining attention.

Grainger (1997) notes that even though MPH may reduce behaviour and attention problems, it does not teach the appropriate skills necessary to learn how to read. As a result, Grainger (1997) recommends the employment of additional strategies when ADHD occurs with learning or reading disabilities. Gulley and Northup (1997) highlight the need for research that employs single-case designs to examine the effects of MPH on ADHD. They state that this is important because they would reduce the chance of subjective teacher and parent judgments that may be biased from effecting the research outcomes.

1.2.2 Other Interventions

The other interventions adopted for addressing the symptoms of ADHD generally involve either cognitive, behavioural, or a combination of cognitive-behavioural approaches.

It has been postulated that the deficits in behavioural control that characterise ADHD and the effectiveness of the stimulant drug treatment, may be explained by an elevated reward threshold. As a result, individuals with ADHD may require more frequent, more immediate and more salient reinforcers to maintain appropriate responding (Solanto et al., 1997). Subsequently, when parent or teacher-administered reinforcers do not effectively sustain on-task performance, the child's behaviour reverts to the control of task-irrelevant stimuli (Solanto et al., 1997). According to this model, the interventions that are successful in treating ADHD produce an increase in the intensity of reinforcement either through behaviour modification programmes, or internally with stimulant drugs, as they are believed to act on brain centers in the medial forebrain that mediate the experience of reward (Barkley, 1997). However, of the limited behavioural research investigating the reward sensitivity of children with ADHD, the results have provided inconsistent and equivocal support. Solanto et al. (1997) studied 22, 6-10 year old children with ADHD, under four conditions in which the separate and combined effects of MPH and a behavioural intervention (reward plus response cost) were examined. Using a signal detection procedure, they found that the ability to discriminate between target and false targets (d') was significantly better with MPH than placebo and exhibited reduced deterioration over time. The contingency treatment improved the mean d', compared to the placebo plus feedback condition, but had no effect on the slope of performance deterioration. The addition of contingencies to MPH did not result in further improvement. Solanto et al. (1997) stated that these results indicate that MPH improved sustained attention, whereas behavioural contingencies did not.

Cognitive-behavioural treatments are another kind of approach adopted for treating ADHD, which involve targeting the problematic overt behaviour by changing covert thought processes (Mathes & Bender, 1997). Self-monitoring is one cognitive-behavioural strategy that is increasingly being recommended for children with ADHD. Barkley (1997) states that self-direction and internalization of speech exert profound control over an individual's behaviour and hence development of self-control. For example, the application of self-directed rules allows the individual to persist in responding in conditions of very low levels of reinforcement or with delays in the consequences of responding. However, these abilities appear to be impaired in individuals with ADHD and can cause a number of problems (Barkley, 1997). Grainger (1997) attributes the attentional and behavioural problems of ADHD with the effectiveness and efficiency of these self-control strategies. Berk and Potts (1991; as cited in Grainger, 1997) found that the private speech of children with ADHD was generally less effective than that of children who appeared to have adequate self management skills. Thus, Grainger (1997) suggested that improvement can result from developing self-management skills with a structured program of self-monitoring, contingency management and on-task training that is linked with identified target behaviours developed in collaboration with the child. Grainger (1997) outlined three stages to training in self-management that include on task training, self-recording and self-monitoring of progress, and school and home-based contingency management. The first step of the programme involves training the child to focus on appropriate on-task behaviour by teaching them an on-task plan that begins to guide the process of self-regulation. Grainger suggests a simple plan that asks, 1) What is my task? (Answer) and 2) Am I doing it? (Yes I am or No I am not), and recommends practising using the plan with a visual or auditory prompt to remind the child to read the plan out loud. Grainger recommends that distracters be present during this training process so that the child can learn to allocate and sustain attention on the task. This intervention strategy is being increasingly adopted in New Zealand schools.

Mathes and Bender (1997) used a similar approach with three male participants with ADHD, aged between 8-11 years of age, selected because of their frequent off-task and inattentive behaviours in the classroom, even though they were taking MPH. Their intervention was implemented by their teacher and involved training in self monitoring according to the procedures developed by Hallahan, Lloyd and Stoller (1982). The participants wore head phones and asked themselves, "Was I paying attention when I heard the tone?" and subsequently recorded the answer on a self-monitoring checklist. Mathes and Bender found a clear functional relationship between the self-monitoring intervention and the considerable improvement for all three participants in the percentage of intervals of on-task behaviour. They also found that the procedure had high social validity with the participants and concluded that a combination of pharmacological interventions and self-monitoring enhanced the participants' on-task behaviour. Barkley (1997) highlights that previous research has found that although initially children with ADHD may adopt a new strategy to help self-monitor, they eventually decline in their adherence to the strategy in later trials.

DuPaul and Eckert (1997) conducted a meta-analysis of the effectiveness of 63 outcome studies examining the effects of school-based interventions for young people with ADHD conducted between 1971 and 1995. DuPaul and Eckert found that the most effective interventions in terms of behaviour change were the contingency management strategies and academic interventions compared to cognitive-behavioural strategies for both Within-Subjects and Single-Subject Design studies, but the cognitive-behavioural strategies were more effective in terms of academic performance. However, they state that the improvement in academic performance may indeed be a function of methodology rather than representive of true treatment differences. It is interesting to note that DuPaul and Eckert found only 63 investigations that explored the effects of school based treatments that met minimal methodological criteria compared to hundreds investigating the effects of MPH.

The research on ADHD rarely highlights what the children can do and what strategies they employ that are beneficial in addressing the symptoms that are often problematic for them. Johnstone and Barry (1996) demonstrated that a group of 10 children with ADHD employed additional cognitive processes by analysing their auditory ERPs when processing task-relevant stimuli compared to age, sex and IQ matched controls during an auditory two-tone discrimination paradigm. They concluded that, even though compared to the matched controls the N2 component was larger in the posterior region than in the frontal region for the participants with ADHD, this appeared to be compensated by the presence of a larger P3b peak recorded in the frontal region.

1.3 Reading and ADHD

New Zealand adopted the "whole language" approach to teaching reading in the early 1970's. The "whole language" approach encourages children to look at the words around a word they are having difficulty with and at the pictures for clues to help them (Clay, 1987). Since this time the "whole language" approach has become a successful internationally marketed industry that remains the dominant strategy in New Zealand primary schools (Wilkinson, 1998). However, Ryan and Openshaw (1996) note that the amount of referrals for specialist assistance and reading failure remains high and that there is an increasing amount of international research that questions the efficacy of this approach. Ryan and Openshaw (1996) highlight that there is a reluctance in New Zealand to critically examine the dominant "whole language" approach to reading and hence develop alternative strategies for successful reading. Ryan and Openshaw state that continued failure to adequately differentiate between groups of children with special needs in terms of reading has contributed to an inability to develop appropriate programs. Wilkinson (1998) examined the comprehension and word recognition scores from 3,027, 9 year old students from a sample of 176 New Zealand primary schools. Wilkinson found that factors that moderated gaps in reading levels were regular assessment of the students' progress and reflected the teachers' capacity to handle diversity and provide an environment rich in literacy. However, Wilkinson proposed that many teachers are struggling to handle the increased diversity among students and are finding it difficult to be responsive to individual needs. In New Zealand the children that have considerable difficulty reading are referred to Reading Recovery programmes and there is evidence that this an effective strategy. For example, Moore and Wade (1998) conducted a longitudinal case study in Australia and New Zealand that compared the reading and comprehension ages of 121 children who had received Reading Recovery intervention at age 6 compared to 121 age-matched children who performed better in literacy. They found that the mean reading age of the ex-Reading Recovery children was nearly 12 months superior and the mean comprehension age was nearly 13 months superior than the comparison group.

Previous research has illustrated that there is a high prevalence of language impairment and reading disabilities (RD) in children with ADHD (Purvis & Tannock, 1997). Grainger (1997) holds that these may be explained by a combination of the level of attention deficit and other factors such as phonemic processing difficulties playing a part in reading failure (Grainger, 1997). These deficits are not what the "whole language" approach focuses on and some say are a failure of the approach (Ryan & Openshaw, 1996). There is an increasing body of research that indicates that a number of clinical and neuropyschological differences exist between children with ADHD who do or do not have a reading disability. For example, Purvis and Tannock (1997) demonstrated that in a study of 14 boys with ADHD, 14 with ADHD and RD, 8 with RD only and 14 controls, both groups of children with ADHD exhibited difficulties in organising and monitoring the re-telling of stories. Both groups of children with RD exhibited deficits in receptive and expressive semantic language abilities and the comorbid group exhibited the deficits of both the ADHD and RD children. They concluded that the deficiencies observed for the children with ADHD were consistent with higher-order executive function deficits, whereas the deficits observed in the children with RD were consistent with deficits in basic semantics and language processing. Further to this, Halliperin et al. (1997) replicated previous research that demonstrated that children with ADHD with a RD have different plasma levels of the noradrenergic metabolite, 3-methyloxy-4-hydroxyphenylglycol (MHPG) than children with ADHD without reading disabilities. They found that among the children with ADHD the plasma levels of MHPG were inversely associated with measures of academic achievement and verbal processing, but not teacher or parent ratings of behaviour or CPT measures of impulsivity and attention. Given the subtleties of the differences they found, they recommended the development of diagnostic measures and interventions that are much more selective.

Previously it was assumed that reading underachievement was a secondary complication of ADHD (Grainger, 1997). Alternatively, a number of researchers have recently begun to question this and propose that it is a result of another deficit that is related to reading failure, with inattention being a non-specific behaviour resulting as a consequence of the fact that the child is having difficulty reading. This failure, Grainger (1997) proposes, could result in increased levels of distractible and inattentive behaviour.

1.4 Visual attention and associated processes involved in reading

The previous sections have highlighted the need for further investigation into the nature of the attention systems of individuals with ADHD (Schachar et al., 1988). This section highlights how this aim can be achieved by studying visual attention using eye tracker technology. Researchers have used methods of eye tracking as an indicator of where individuals focus their attention in a variety of testing conditions. For example, using the eye tracker Land and Lee (1994) found that drivers direct their gaze to the tangent point on the inside of curves when steering on the open road.

Attentional processes help the human visual system select which information is important from the continual presentation of visual stimuli (Carlson, 1987). To enable a stimulus to be looked at in detail the eyes move to bring the image of the stimulus onto the fovea, which is a small area near the centre of the retina (Ruff & Rothbart 1996). This process is referred to as accommodation and allows the shift of attention and the movement of the eyes to be initiated and bring the stimulus from peripheral to central vision (Corbetta & Shulman, 1998). The detection of an object is often initiated in the visual periphery and is the precursor to eye movement (saccade) and a subsequent fixation on the object in the foveal region (Robinson & Goldberg, 1978). Indeed some visual events may be detected and processed in the peripheral region, whereas other events may only be partially processed in the visual periphery requiring a saccade for detailed examination (Holmes, Cohen, Haith & Morrison, 1977). Kahneman (1973) states that foveal vision covers a two degree area in the field of view, with the remaining area being processed by peripheral vision.

Saccadic eye movements bring stimuli into foveal vision through quick adjustments to enable visual exploration (Andreassi, 1989). Therefore, saccades are used whenever it is necessary to redirect the line of sight and generally move from point to point several times each second. The information is gathered during fixations when a stimulus is brought onto the fovea and occurs between saccades (Wurtz, Goldberg & Robinson, 1982). The manner in which the information from the successive fixations is synthesised and interpreted is affected by a number of factors including, knowledge and past experience of the world and physical laws. When stimuli are novel, complex, incongruent or when such objects are perceived in the periphery, attention will be diverted to them (Kahneman, 1973).

Visual information is thought to be integrated in a two stage process. Firstly, the individual quickly gathers general information about a scene to develop a general formulation (Ruff & Rothbart, 1996). Secondly, the individual must encode more precise information about the stimulus (Ruff & Rothbart, 1996). Advances in technology have aided the increased understanding of the processes that underlie visual attention. Functional anatomical studies suggest the covert allocation of attention across a variety of visual tasks is mediated by a set of neural signals in the parietal and frontal cortex (Corbetta & Shulman, 1998). Corbetta and Shulman (1998) suggest that shifts in attention to different visual locations or stimuli involve cortical areas responsible for oculomotor programming and execution. Schall and Hanes (1998) investigated and concluded that the frontal cortex plays a central role in the production of purposeful eye movements and that the neural processes in the supplementary eye field do not participate in the control of eye movements but seem to monitor performance.

It is generally held that during the course of a saccade visual perception and cognitive processes are suppressed (Desmurgent et al., 1998). Takeda, Nagai, Kazai and Yagi (1998) proposed that saccadic suppression may reduce excessive visual input. In their study, where 12 university students were required to identify moving patterns, they found that when the students fixated on a single point the correct responses were near chance, but improved significantly when they made a saccade across the moving pattern. Alternatively, there is increasing evidence that cognitive processing is not entirely suppressed during saccades. Irwin (1998) demonstrated that lexical decision latency and accuracy were not affected by the distance of the saccade and that there was a reduction in the post-saccadic processing time compared to after a short saccade. Therefore, Irwin concluded that lexical processing is not suppressed during saccades and proposed that saccade durations should be considered in eye movement studies of reading. Irwin and Gordon (1998) examined the role of attention in the encoding of information across eye movements by presenting adult readers with a letter area presented in different fixation points after making saccadic eye movements to new locations. They found that the accuracy of the participants' reports were not only high for the positions they were instructed to attend to, but also for the positions near the saccade target, even when they were told to attend in another position. They proposed that these results indicate that attention determines what information is encoded into trans-saccadic memory and thus remembered across eye movements. Irwin and Gordon hold that because attention precedes eye movement it is probable that information near the saccade target is also encoded.

Munoz, Broughton, Goldring and Armstrong (1998) investigated the age-related changes in saccadic task performance of 168 typical participants, between 5-79 years of age. Munoz et al. found that children aged between 5-8 years characteristically had the slowest and greatest intra-participant variance in the time taken to the onset of the eye movement and the most direction errors in the anti-saccade task. Munoz et al. hypothesised that the strong age-related effects observed in participant performance characterised different stages of normal development and degeneration in the nervous system. Ruff and Rothbart (1996) state that scanning can be defined more generally as shifting attention from one object or event to another in the environment. Although, they stress that while eye movements can be observed directly, the shifts in attention can only be inferred. For example, infant studies have revealed that long looks are not an adequate reflection of attention span. For this reason Ruff and Rothbart hold that to make inferences about the role of attention in performance and learning studies one should include measures of attention independent of measures of performance.

They also state that physiological manifestations of attention are also related to learning and performance.

In a review of the studies of eye movements in reading and other information processing tasks over the last 20 years, Rayner (1998) notes that the basic premise is that eye movement data reflect moment-to-moment cognitive processes. These studies generally consider the characteristics of the eye movements and eye movement control, integration across saccades and individual differences. The idea behind the reading training procedure used in this research was to design a tool to redirect their attention practically whilst reading based on their specific deficits. The effectiveness of designing training procedures for visual attention for individuals with a psychological disorder was demonstrated by research undertaken by Frea (1997). Within a multiple baseline design across settings, Frea demonstrated that the stereotypic behaviour of two adolescents with autism could be reduced by training them to increase their orienting responses to their environment by using an external prompt.

The study of eye movements when reading has provided valuable information about the nature of reading for typical readers and readers with identified RDs. Eden, Stein, Wood and Wood (1995) investigated whether disordered language processing was the main cause of the children's reading problems or whether visual problems played a role by studying the eye movements. Eden et al. found that the 93 children with RDs performed poorly on verbal tests and were significantly worse at many visual and eye movement tasks. They found that a high proportion of the variance (68%) in reading ability could be predicted by combining the phonological and visual scores in multiple regression. Thus Eden et al. proposed that reading disability could result, to some degree, from the dysfunction of the visual and oculomotor systems. Differences in eye movement behaviours have been found for individuals with dyslexia. Biscaldi, Gezeck and Stuhr (1998) found a significant correlation between abnormal saccadic control and reading disability in a study of 185 participants aged between 8-25 years. The participants were divided into either an average reader group or a group for participants with dyslexia separated into two subgroups, participants with dyslexia with deficits in the serial auditory short-term memory or with an isolated low achievement in reading/writing. Biscaldi et al. measured the saccadic eye movements in a single target and in a sequential target task analysing the various aspects such as the saccadic reaction times, number of regressive saccades and number of late saccades. They found, in an estimated 50% of the participants with dyslexia, significant variations from normal performance in the saccadic variables, compared to 20% of the control participants. However, like the controls they found that the level of saccadic performance improved with age for the participants with dyslexia. Biscaldi et al. hypothesised that these findings indicate that the reading process and saccade system are controlled by both visuo-spatial attention and fixation systems that perhaps are impaired in a number of the participants with dyslexia.

The training procedure used in the current research was developed based on previous research that has used the findings of eye movement analysis with various conditions to develop appropriate strategies to help with reading. For example Trauzettleklosinski (1997) used analysis of the eye movements and the retinal fixation focus to explore the reading strategies adopted by 36 patients with hemianopic field defects (HFD). Trauzettleklosinski found that 10 participants showed an eccentric fixation and hence shifted the presentation of the stimuli 1-2 degrees towards their healthy hemiretina creating a sufficient reading field and subsequently increasing the reading speed. In subsequent research, Trauzettleklosinski and Brendler (1998) investigated the eye movement patterns in HFD in more depth with an emphasis on the importance of clinical parameters. They found that the clinical parameters such as the hemispheric location of the HFD, the distance to the visual field center and the time since onset are significant parameters for reading performance. Trauzettleklosinski and Brendler concluded that analysing clinical parameters in correlation with reading performance provides valuable information relating to learning effects and can aid subsequent rehabilitation.

Research examining eye movements and reading have identified a number of frequently observed behaviours. Reichle, Pollatsek, Fisher and Rayner (1998) state that often when reading individuals will skip or only briefly fixate on words that are frequent, short or predictable. Daneman and Reingold (1993) state when readers have difficulty with a word the length of time that they fixate on a word increases. Re-focussing on words is often associated with facilitating the many aspects of processing reading requires (Raney & Rayner, 1993). It has been observed that often readers will return, regress in a leftward direction for readers of English, to previously read words (Altmann, 1994). Rayner and Raney (1996) found that readers looked longer at low-frequency words than at high-frequency words when analysing their eye movements. However, Rayner and Raney found that there was no frequency effect when the participants searched through texts for a target word and proposed that the decision to move eyes during reading is made on a different basis than they are during visual search. On the other hand, not all researchers agree that there is value in including a regression-contingent measure when analysing eye movements when reading (Altmann, 1994).

Pearson, Yaffee, Loveland and Norton (1995) investigated the hypothesis that children with ADHD have developmental immaturities in overt attention compared to non-ADHD peers. A group of children with and without ADHD were instructed to direct their attention to a central fixation cue and then subsequently cued by both central and peripheral cues to direct their attention to either the left or right peripheral fields. Pearson et al. found that the performance of the children with ADHD was more disrupted when their attention was misled by invalid cues, particularly during longer intervals and was reflected in their significantly higher error rates. The performance of the children with ADHD was characterised by attentional "waxing and waning" for the longer time intervals. They concluded that the results did not support the hypothesis that children with ADHD had developmentally immature covert attention skills, but suggest the possibility of global developmental immaturity of their attention skills.

One of the main aims of this research was to develop a diagnostic procedure based on examining the eye movements of children with ADHD. Although this is a new area of research in terms of diagnosing ADHD, there is increasing evidence of the effectiveness of examining eye movements in aiding the diagnosis and assessment of schizophrenia. Previous research with adults with schizophrenia has revealed that they have less frequent eye fixations and a limited area of inspection (Matsushima et al., 1998) and abnormalities in smooth pursuit eye movements (Jacobsen et al., 1996). Based on this previous research Matsushima et al. (1998) found that by examining the exploratory eye movements, individuals with schizophrenia could be discriminated from individuals without schizophrenia with a sensitivity of 77% and a specificity of 81%. Similarly Arolt et al. (1998) found a concordance between clinical diagnosis of schizophrenia and eye movement dysfunction (kappa = .67-.80). As a result Arolt et al. concluded that individuals with the residual subtype of schizophrenia could be differentiated from controls with considerable criterion validity based on analysis of smooth pursuit tasks and voluntary saccades. Jacobsen et al. (1996) presented 17 children with schizophrenia, 18 children with ADHD and 22 typical children with a smooth pursuit eye tracking task. Jacobsen et al. found that the children with schizophrenia had significantly greater smooth pursuit impairments than either the controls or the children with ADHD, but did not observe a significant relationship between eye movements and clinical variables. Recent research by Karatekin and Asarnow (1998) explored the nature of the previously observed visual search impairments in individuals with schizophrenia. They established the search rate from the slope of search functions and duration of the initial stages of search from the time taken until the first saccade on each trial by presenting children with schizophrenia, ADHD and age-matched controls on tasks that tap parallel and serial search. They concluded that the manual response types for both clinical groups were elevated but that only the children with ADHD exhibited delayed initiation of serial search. It is important to note that these studies did not focus on the role of attention, the fundamental aspect of ADHD.

1.5 The aims and hypotheses of the present research

The aim of the research was to develop objective diagnostic measures and to explore the feasibility of developing a new reading training procedure for children with ADHD using the visual attention paradigm and eye tracking technology. Detailed procedures for the successful calibration of eye tracker technology are not available for children, let alone children with ADHD, as far as is known. Therefore, the main challenge of this research was to design an appropriate calibration procedure that would allow the use of an eye tracker on children with ADHD so that their eye movement behaviour could be studied while they were reading.

The idea was to use a small clinical sample of children with ADHD in order to provide preliminary data to test the new diagnostic measures based on eye movement behaviours and to evaluate the accuracy of the calibration procedure (Experiment 1). Additional to the study of eye movement behaviour in children with ADHD, this experiment aimed to measure the distractibility, body movements and reading performance compared to age and reading matched controls without ADHD. For Experiment 1, it was hypothesised that the participants with ADHD would have different eye movement behaviours (e.g., more erratic, different patterns) than the participants that did not have ADHD. It was also hypothesised that the analysis of the eye tracker results would correspond with the paediatrician's diagnosis of ADHD and with the CTRS-R and the CPRS-R. It was hypothesised that there would be a relationship between the pattern of eye movements and the level of motor activity of the participants who had ADHD. It was also hypothesised that there would be a difference in the eye movement behaviours when the participants were reading aloud as opposed to silent reading, which would be more pronounced for participants with ADHD. It was hypothesised that MPH medication would change the eye movement behaviour and result in a reduction of the number of leg and arm movements in the participants with ADHD, compared to those not receiving MPH.

Finally, an attempt was made to explore the feasibility of developing a reading training procedure (Experiment 2) that would provide computerised visual guidance for the participant's reading position and would include visual prompts based on those suggested by Grainger (1997). It was hypothesised that the computerised visual guidance would help all children maintain their attention, as indicated by eye movement behaviour and reading performance measures.

2. GENERAL METHOD

2.1 Ethical approval

Ethics approval was obtained for this research from the Psychology Research and Ethics Committee of The University of Waikato.

2.2 Apparatus

For both experiments, the participants were seated in a comfortable *car seat* facing a complete *dashboard* of a car, which included a working steering wheel (see Figure 2.2.1). This *steering wheel* was connected to a potentiometer that measured the steering wheel movements.

An *eye tracking system* (4000SU) from Applied Science Laboratories (1990) was used to measure the eye movements of the participants (for a detailed description of the eye tracker refer to the Applied Science Laboratories Manual (1990)]. The eye tracking system consists of a visor, an optics module, and eye and scene cameras mounted on a sports-type helmet (see Figure 2.2.2). The eye tracking system uses the corneal reflection bright pupil method to monitor the participant's visual points of interest. This information is translated into an electronically produced single cursor point and is simultaneously and continuously recorded on videotape, via a *video recorder* (Mitsubishi VCR, model HS-E82). The eye tracker measures the participant's eye line of gaze with respect to the head, so head movement is possible. During the trials the scene and eye movements were monitored to indicate the pace of story presentation on two sony black and white *video monitors* (model PVM-122CE). The visor reflects an image of the eye into the eye camera and reflects an image of the viewed scene towards the scene camera. The visor is coated on one side to reflect the infrared light from the illuminator in the optics module as the coating material reflects energy that is in the near infra red region, whilst transmitting visible light energies. Two hinged telescopic arms mount the visor to the helmet and enable the angle of the visor to be adjusted to maximise the reflection of the image of the eye and scene. The scene camera records the scene reflected from the visor of the images in front of the participant. It is mounted on the helmet by the left eye, with an adjustable boom arm that allows the camera to be positioned to maximise the amount of scene recorded. The optics module consists of the eye camera, an illuminator tube and a number of mirrors and prisms. This is mounted on the helmet above the left eye by a dovetail slide that allows the optics module to be positioned above the participant's pupil. This maximises the efficiency of the projection, alignment and recording of the illuminator beam that is reflected from the participant's cornea and retina. Both the eye and scene cameras are connected to a camera control unit (CCU) which contains most of the camera electronics. The CCU connects the cameras with the eye tracking system control unit (ETSCU). The ETSCU interprets the information transmitted from the CCUs. The ETSCU facilitates the adjustment of the intensity of the illumination beam and the discrimination of the pupil and corneal reflections. A lap top computer (Mitac) was used to control the ETSCU.

The computer generated text was projected onto the screen using a *video projector* (Sanyo LCD, model PLV–IP). The slide for the picture distracters and the original calibration process were projected using a *slide projector* (Kodak Ektapro 7010).

The presentation of the text was controlled by a *laboratory computer* (Pentium II Dell OptiPlex GXa). The *computer* also recorded the time taken to read each story and words read per minute. The computer recorded the angle of movement for the steering wheel, up to and including -90 degrees and +90 degrees, every 250 ms, as a measure of arm movement.

The amount of leg movement was measured by attaching two battery operated *Light Emitting Diodes* (LEDS) to the lower shin area of each leg. The pair of LEDS for each leg were powered by two AA Energizer batteries. A *video camera* (Panasonic VHS.625 – MS1 with a X10 Power zoom lens) recorded the movement of the LEDS for the duration of each session.

A Sony six Channel Stereo Mic Mixer amplified the participants' verbal responses throughout the sessions and were recorded on the video recorder. To ensure the maximum quality of the verbal data the microphone was placed on the dashboard immediately in front the participants

2.3 Experimental Stimuli

Figure 2.3.1 illustrates the view of the stimuli from the participant's perspective. On the right is the *text*, on the left is the *picture distracter* and at the bottom is the *sheep distracter*.

2.3.1 Text

For all sessions in both experiments, each participant read four stories, referred to individually as trials. The stories presented were separated into two groups to match the two different reading levels of the participants. The stories for the beginner readers were taken from the PM Junior School readers that were aimed at the red reading level of the colour wheel classification system from the Ministry of Education. The second group of stories were taken from a selection of New Zealand School Journals, aimed at a 7-8 year reading level. Considerable effort was made to select stories that reflected New Zealand lifestyles, issues, places and people. The suitability of the stories chosen were discussed with two primary school teachers, who also acted as cultural advisers as required.

The computer generated text was projected on to a white painted wall 3 m from the participants and covered an area of 1.50 m x 1.73 m . Thus, this area covered a visual angle of 33 deg. The white lettering of the text was presented against a dark blue background to maximise the pupil size for ease of calibration and subsequent data analysis. The length of the letters displayed was 7cm (3 deg) with a width of 4cm (2 deg). The order of the text presentation was the same for each participant in their relevant group. The texts for each session were programmed into the computer prior to the session and a blank screen appeared between each story, thus ensuring that the next story could begin when the participant and researchers were ready. A research assistant controlled the pace at which each page of text was presented as it was often not possible to present the complete story on the screen given the limited space available.

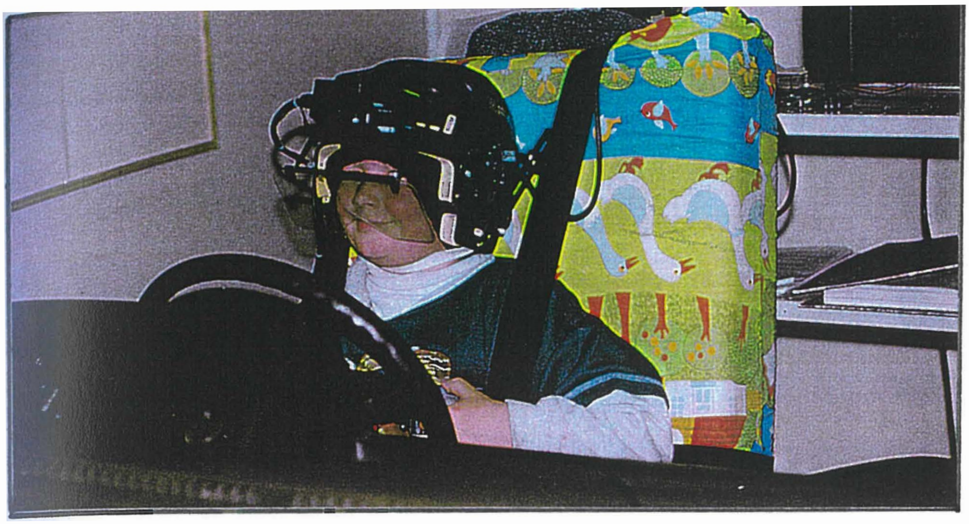


Figure 2.2.1. The participants were seated in a comfortable car seat, facing a complete dashboard of a car. Included in this figure are the modifications outlined in section 3.3.2.

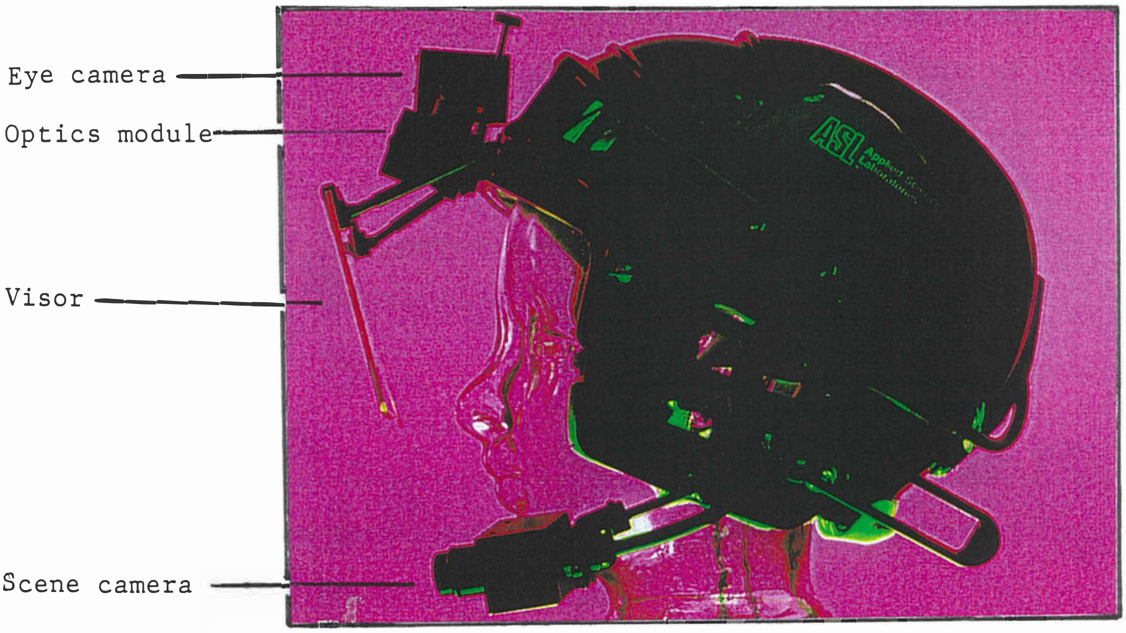
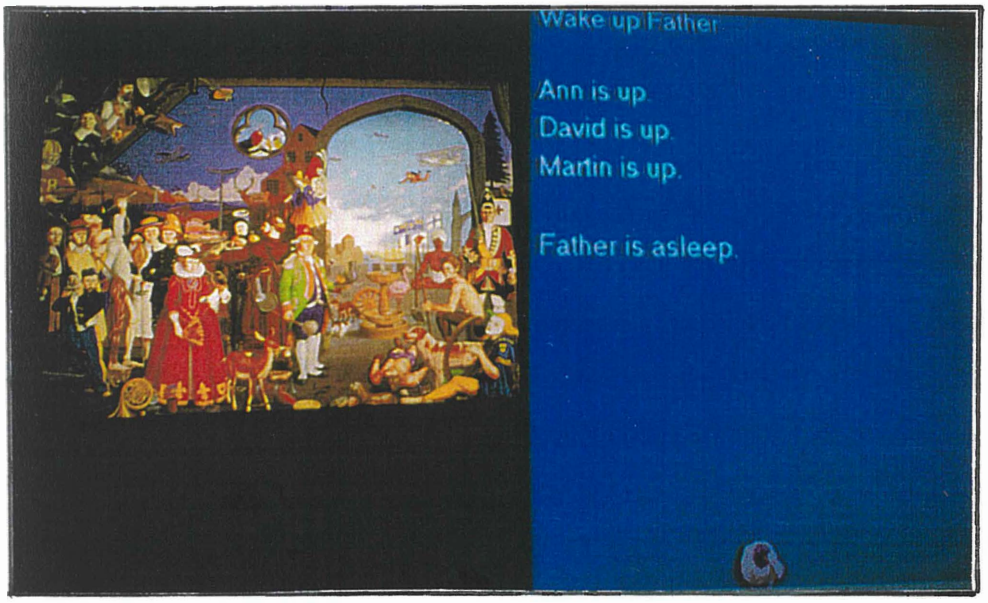


Figure 2.2.2 The eye tracker helmet.



Wake up Father

Ann is up.
David is up.
Martin is up.

Father is asleep.

Figure 2.3.1. View of the presented stimuli from the participants' perspective. On the right is the text, on the left the picture distracter and at the bottom the sheep distracter.

2.3.2 Picture distracter

The picture distracters were taken from the book, *The Ultimate Alphabet*, by Mike Wilks (1987; see Appendix 1). The area of the pictures varied depending on the nature of the picture and ranged from a portrait presentation, 0.95 m x 1.28 m, resulting in a visual angle of about 25 deg, to a landscape presentation of 1.28 m x 0.94 m, resulting in a visual angle of about 18 deg.

2.3.3 Sheep distracter

The second distracter consisted of a computer-generated animated sheep that randomly moved around the screen. The sheep also performed a variety of random acts, such as eating and being captured by aliens. The programme was downloaded as free software from a website for screen savers on the Internet. The screen area that the sheep covered was 2.04 m x 1.73 m. covering a visual angle of 38 deg. The actual sheep was 0.15 m in width and length, resulting in a visual angle of about 3 deg. The sheep was presented at the beginning of the first trial for each session and was removed at the completion of the last trial.

2.3.4 Puzzles

A variety of puzzles for children (e.g., "Where's Wally?") were used throughout the experiments. They were projected via the slide projecter onto the same area as the picture distracters (see Appendix 2).

2.5 Behaviour variables

The following behaviour variables were collected and analysed for each session and divided into the category of text read aloud or silently.

Duration of fixations and angles of saccades: The eye movement behaviour for each child was analysed manually frame by frame for each story, with each frame lasting 40 ms. The angles of saccades (lines of gaze) were transcribed on to transparencies from the eye movement videos. The duration of each fixation was also recorded onto the transparencies using different symbols for four time intervals; 0<250 ms, 250<500 ms, 500<750 ms, 750<1000 ms. For each participant, the percentage of time spent looking at the text, the two types of distracters, and any `other' area of the presented screen were recorded. This analysis procedure was cross-checked by a research assistant to ensure consistency.

Words read per minute: The time taken to read each story and the number of words read per minute was recorded by the *laboratory computer*.

Story comprehension: The participants' comprehension of each story was measured by their verbal responses to two questions asked by the main researcher at the end of each story. These verbal responses were recorded on the *video recorder* via the *stereo mixer*.

Accuracy of picture distracter identification: Previous research has indicated that simply looking at an object does not necessarily mean the information is processed and remembered (Ruff & Rothbart, 1996). Therefore, in order to measure the level of information processing, at the end of each session the participants were presented with an array of A4 colour photocopies consisting of two picture distracters that were actually presented during the session, and six that were not, but were from the same source (Wilks, 1987). They were required to verbally indicate which pictures they remembered from the session just completed.

Number of leg movements per minute: Leg movements were recorded by the *video recorder* during each trial. For the analysis of this data, one leg movement was classified as any movement more than 1 cm in any direction, for each leg. Number of leg movements per minute was calculated for each trial.

Cumulative angles of arm movements (degrees): Arm movement was measured by recording the amount of steering wheel movement during each trial. The participants were instructed to hold onto the steering wheel, positioned in front of them, for the duration of each trial. The angle of movement, up to and including -90 degrees and +90 degrees, was recorded every 250 ms by the *laboratory computer*. Cumulative angles of arm movements (in degrees) were calculated for the first story read aloud and silently for each session in both experiments.

2.6 Participants

2.6.1 Selection criteria

The required participants with ADHD were males, aged between 7-9 years, who had a diagnosis of ADHD from a paediatrician for a minimum period of four months and who were receiving MPH treatment. Confirmation of the diagnosis of ADHD, was obtained by administering both the Conners' Teacher Rating Scales - Revised (CTRS-R) and the Conners' Parent Rating Scale - Revised (CPRS-R). Specifically, they were required to obtain a t-score of 65 or above on the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total subscales. If it was not part of the children's regular MPH regimes to have weekend breaks, their paediatricians were contacted regarding any concerns they might have about their client participating in this research given the delays in administration of the medication.

The minimum reading level required for selection was the red level as indicated by the current colour wheel classification system. The red level approximates a five year old reading level under the old system of classifying Junior School readers.

The selection criteria for the control male children required that their chronological age and reading level matched that of the participants with ADHD. They were required to have never received a diagnosis of ADHD, and this was confirmed by obtaining a t-score of less than 65 on both the subscales outlined above.

All the participants selected were required to have no known visual problems, no physical or learning disabilities, no overt neurological deficits, no chronic medical conditions, or any comorbid psychological disorders.

2.6.2 Participant recruitment procedure

Permission was requested and granted by the Waikato Branch of the ADHD Association (Appendix 3) to include a letter in their bi-monthly newsletter that asked for volunteers with ADHD, aged between 7-9 years of age, to participate in the research (Appendix 4). Subsequently, interested parties were sent a letter outlined the research in more detail (Appendix 5). Permission was also requested and granted from the principal of Knighton Normal School (Appendix 6) for a letter to be given to the children aged between 7-9 years of age, without a diagnosis of ADHD, to take home to their parents and/or caregivers (Appendix 7) In both cases, interested parties returned the attached form to the researcher who then contacted them by phone to arrange a further meeting. Interested parties not required for the research were sent a thank you letter.

1. Children selected for the initial meeting were those that met the selection requirements outlined in section 2.6.1, as indicated on the forms completed by their parents/caregivers. Interested parties were offered the option of having the initial meeting in the Clinical Psychology Research Laboratory, at The University of Waikato or in their own homes.
2. The researcher introduced herself to the parent/caregiver and to the child and provided a brief verbal outline of what would happen in the initial meeting so that the child was aware of what was to be expected and thus minimise anxiety. The nature of the research and the requirements of the child were discussed and any questions answered. At this point it was emphasised that the research procedure was not a test and that the child was only required to do his best, a point reiterated throughout the research procedure. It was stressed that the child, or the parent/caregiver, was free to stop the experiment, for the day or completely, at any point and that this would not affect their relationship with either The University of Waikato or the relevant referral source.
3. The CPRS-R was explained to and completed by the primary parent/caregiver of all of the participants. During this time the child selected a game from a choice of three to play after completing a reading comprehension task. The reading comprehension task consisted of the participant reading a journal story at the level indicated by the parent/caregiver. A running record of the accuracy of the reading task was kept and the answers to the comprehension questions were recorded. The child's history of receiving Reading-Recovery was also collected. After this task was completed the main researcher spent 15 minutes playing games with the child to build rapport.
4. Permission was requested and granted to make contact with the child's teacher to complete the CTRS-R. The parent/caregiver subsequently informed their child's teacher that they had given their permission for him/her to complete

the rating scale. The researcher introduced and explained how to complete the form to the teachers and they completed it in their own time. The completed forms were collected from the teacher or returned in an attached stamped envelope. During this contact the child's reading age and participation in reading recovery was confirmed.

5. Appointment times for selected participants were arranged by phone and any transportation difficulties discussed. Petrol vouchers were made available if the participants lived out of town.

6. For the remainder of the research pseudonyms will be used in order to protect the children's identities.

2.7 General experimental procedure

In order to investigate the effects of the order of presentation of the stories, each participant was randomly assigned to either read the first two stories aloud or silently, and to read the remaining two stories using the alternative reading method. Each participant completed the procedure individually.

1. Each participant and their parent/caregiver was taken to the experimental room and shown the equipment, with questions being encouraged. Those accompanying the participant were welcomed to stay during the session and sat quietly at the back of the room. The eye tracker helmet was then placed on the participant's head and foam pads were used to adjust the size appropriately. The participant verbally indicated when he was ready for the calibration procedure to commence.

2. After the eye tracker was successfully calibrated, the participant completed four different trials where he was presented with the experimental stimuli as outlined in section 2.3. The picture distracters were projected and removed in unison with each story. After two stories, the participant was given the opportunity to relax and/or complete a puzzle. After each story the verbal responses to the comprehension questions were recorded.

3. The participant was given the opportunity to complete another puzzle before the equipment was removed.

4. The participant was asked to indicate which picture distracters he saw from a selection of eight picture distracters (see section 2.4.2) and his verbal responses were recorded.

5. Light refreshments and games were made available after each session for all the participants and those that accompanied them.

3. EXPERIMENT 1

The aim of this experiment was to specifically design an eye tracking calibration procedure for children with ADHD so that their eye movement behaviour can be analysed. Given the success of this development, new diagnostic measures will be explored involving a reading task embedded in distracters. The measures will include the participants' eye movement behaviour, the percentage of time spent looking at the text and the distracters, the number of words read per minute and their responses to comprehension questions. In an attempt to obtain data that covers all of the possible hyperactive components of ADHD symptomatic behaviour, the amount of arm and leg movements were also recorded and analysed. Similarities and differences will be compared over two identical sessions within and between the participants with ADHD (with and without MPH) and their matched controls.

3.1 Method

3.1.1 Apparatus

The apparatus as described in section 2.2 was used.

3.1.2 Participants

Three children (pseudonyms: "Mike", "Jason", and "John") were selected as described in the participant recruitment procedure (section 2.6.2). However, it proved difficult to recruit a larger clinical sample of children with ADHD through the channels outlined above. Therefore, two more children with ADHD were recruited using a different recruitment method. A clinical psychologist introduced the outline of this research to the multi-disciplinary team at the Child Development Centre, Health Waikato. The clinical psychologists and paediatricians then introduced the research to the parents of children with ADHD when they saw them for regular appointments. Those interested initiated contact with the researcher by phone and an information sheet and form were sent to them to complete (Appendix 5) and a time for an initial meeting was made.

It is important to note that the participants did not necessarily complete each session on the same day as the procedure needed to be responsive to the fact that two of the children spent alternate weekends with their fathers. To equalise any potential differences in performance, each participant completed each session after a two week interval.

Participants in the beginning readers group:

Max (ADHD): Max was a European male who was 8.1 years of age. He was diagnosed with ADHD by a multi-disciplinary team over a year ago. He was a beginning reader on the red level of the colour wheel classification system and was undertaking Reading Recovery through his primary school and SPELD. Max's T-scores on the CPRS-R for the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total were, 82, 79 and 84 respectively. Max's T-scores on the CTRS-R for the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total were, 69, 78 and 71 respectively. Therefore, both the CPRS-R and the CTRS-R meet the screening criteria for ADHD which support the paediatrician's diagnosis of ADHD.

John: John does not have a diagnosis of ADHD and was the matched control for Max and Andrew. John was a European male, who was 8.1 years of age. His reading level was at the red level on the colour wheel classification system and had never received Reading Recovery. John's T-scores on the CPRS-R for the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total were, 47, 47 and 44 respectively. His T-scores on the CTRS-R for the Conners' ADHD Index, Conners' Global Index: Total and DSM-IV: Total were, 49, 50 and 47 respectively. These results provided no indication of symptoms that would suggest a diagnosis of ADHD.

Andrew (ADHD): Andrew was a European male, who was 7.5 years of age. Andrew was diagnosed as having ADHD after a team assessment four months prior to participating in this research. Prior to the research Andrew had completed approximately three months of Reading Recovery provided by his primary school and was identified as reading at the red level of the colour wheel classification system. Andrew's teacher did not return the original CTRS-R and completed another seven weeks after the completion of the data collection. The teacher said that the form she filled out originally was different from the one now provided as his behaviour had changed considerably, which she attributed to the MPH medication. Therefore, it is highly likely that obtained scores on the CTRS-R are not representative of how he was at the time of testing. Andrew's T-scores on the CPRS-R for the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total were, 68, 82 and 72 respectively, providing support for his diagnosis of ADHD. However, his T-scores on the CTRS-R for the Conners' ADHD Index, Conners' Global Index: Total and DSM-IV: Total were, 46, 48 and 48 respectively, which do not support a diagnosis of ADHD, in the classroom setting. However, the parties involved in Andrew's management of ADHD are certain he had and still has ADHD.

Participants in the 8 year old reading level group:

Jason: Jason was a European male who was 7.3 years of age. His current reading age was estimated at an eight year old level after receiving ongoing Reading Recovery from a private tutor. Jason's T-scores on the CPRS-R for the Conners' ADHD Index, Conners' Global Index: Total and DSM-IV: Total were 57, 53 and 58 respectively. On the CTRS-R his T-scores for the Conners' ADHD Index, Conners' the Global Index: Total and the DSM-IV: Total were, 54, 58 and 55 respectively. Therefore both the CPRS-R and the CTRS-R do not meet the screening criteria cut-off point for ADHD, however the sub-scales are elevated which may indicate a global problematic functioning or co-morbidity (Conners, 1997). Due to unforeseen circumstances, Jason's CPRS and CTRS were not completed until after the first diagnostic session. Therefore, it was only after he began participating that it was discovered that he did not meet the participant selection criteria, even though he had received a diagnosis of ADHD by a paediatrician, approximately six months prior to participating in the research. It was decided to continue to include Jason in the research as it was deemed a unique opportunity to compare the findings of this study, in terms of differences in his eye movements, with those who had a diagnosis of ADHD that was confirmed by their scores on the CPRS-R and CTRS-R.

Mike: Mike does not have a diagnosis of ADHD and was the matched control for Jason. Mike was a European male, who was 7.10 years of age. Mike's estimated reading age was 8.6 years and he had never received Reading Recovery. Mike's T-scores for the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total were, 53, 53 and 54 respectively. His T-scores for the Conners' ADHD Index, the Conners' Global Index: Total and the DSM-IV: Total were, 54, 47 and 58 respectively. These results provided no indication of symptoms that would suggest a diagnosis of ADHD.

3.1.3 Experimental Procedure

This experiment consisted of two sessions. For both sessions the general experimental procedure was used as described in section 2.7.

3.2 Session 1 (First calibration attempt)

3.2.1 Participants

Due to difficulties obtaining a clinical sample of children with ADHD, at this stage the participants were Jason, John and Mike (see section 3.1.2 for a detailed profile of these participants).

3.2.2 Procedure

The general experimental procedure (section 2.7) was used. It was reviewed with the participants and their parent/caregiver and any questions answered. Informed consent forms were discussed and signed (Appendix, 7).

None of the children with ADHD who received medication received their normal morning dose of MPH until after the session was completed. A research assistant supervised the participants for a maximum of 1 h 30 min until the MPH took full effect. During this time light refreshments were made available to the participants and those accompanying them.

In this session, it was first attempted to calibrate the eye tracker for the first time on children with and without ADHD. At this stage the standard calibration procedure was used as described in detail in the eye tracker instruction manual from Applied Science Laboratories (1990).

1. First it was demonstrated to the child how the equipment worked on a research assistant and when the participant felt comfortable, the equipment was attached to him.

2. A ‘calibration slide’ was projected on the wall covering an area of 0.95 m x 1.28m (25 degrees visual angle). The slide consisted of nine black target dots, three across and three down spaced evenly over a white background. They were about 0.02 m in radius producing an image of about 1 degree visual angle each.
3. The participant was then required to look at each dot in a predetermined order while keeping the head as still as possible for at least two minutes. The success of the calibration depended on the ability of the children to keep their head still. The participants were verbally reinforced for keeping their heads still, and were able to complete a “Where’s Wally?” puzzle at the end of the calibration as a reward. However, when the researchers had difficulty calibrating the eye tracker the participant completed the “Where’s Wally?” puzzle after two calibration attempts as to give the child a break.

3.2.3 Result and Discussion of first calibration attempt (Session 1)

During the first calibration attempt a number of problems with the method of calibration became apparent. It proved to be very difficult to calibrate the eye tracker for each participant, taking a minimum of four attempts each. This was due to a number of reasons that primarily centred around the fact that the participants had difficulty keeping their head still and that they did not look at the dots for long enough to allow accurate calibration. As a result, when the process of calibration was achieved it was not accurate enough to allow a detailed analysis of the eye movement behaviour. Specifically the accuracy of the point of focus was out by an error of about 4 degrees visual angle or more. It was realised that the standard calibration procedure from Applied Science Laboratories (1990) was designed for adult participants who are able to focus on black target dots over a longer period of time without moving their head. Therefore, based on these limitations a number of modifications to the standard calibration procedure were developed and it was decided that the process of data collection would begin again with these improvements included.

The main focus of the changes was to decrease the time the children had to sit still, from two minutes to approximately one minute. It was also deemed necessary to provide the participants with extra support for the head given the weight of the helmet. Another improvement was to change the calibration slide to help the participants to focus in the required area, and to make what they were looking at more interesting so as to maintain their attention.

3.3 Second calibration attempt (Session 1)

3.3.1 Participants

All participants described in 3.1.2 completed this Session.

3.3.2 Procedure

The general experimental procedure (section 2.7) was used. The general procedure for the calibration remained as outlined in section 3.2, however a number of practical modifications were made. One of the major changes was replacing the ‘calibration slide’ used for the standard calibration procedure from Applied Science Laboratories (1990). The target dots were replaced by white numbers that were presented against a dark blue background so that the participants pupil size would be larger and hence facilitate the pupil recognition process during calibration. The presentation of the new calibration screen and the numbers was controlled by a research assistant using the *laboratory computer* and the *video projecter*.

The participants were asked to look at the required number for the calibration process, and this number simultaneously changed size and colour whilst it was rotating at the control of the research assistant. The colours varied from white to green to red and back to white and simultaneously changed from being a size of 0.06 m x 0.03 m to 0.14 m x 0.08 m in width. This produced a changing visual angle from approximately 1 degree to 3 degrees. The size of the area calibrated was increased so that accurate information was available for a wider area of eye movement. The new screen was 1.68 m in width and 1.62 m in length (about 33 degrees visual angle) so that the eye tracker was calibrated for a larger area to facilitate later analysis.

Modifications were also made to the standard car seat used for this research (see Figure 2.2.2). A foam cushion was placed behind the participants to help them sit straight and enable them to rest their head with the helmet on. Modified seat belts were designed using two velcro straps that went over each shoulder and joined onto a lap seatbelt. This provided support for the head and helped them to sit still without restricting the arm and leg movements as these were important behavioural variables to be considered.

3.3.3 Results and discussion for second calibration attempt (Session 1)

The modifications made improved the calibration process considerably as the mean calibration time was approximately one minute and the accuracy of the calibration produced a visual angle error of less than one degree. The modifications also resulted in a reduction in the number of attempts at calibrating, with only John requiring two calibration attempts. The two shoulder seat belts proved beneficial in helping the participants keep their heads still, even if their arms and/or legs moved. It is important to note that the calibration process only took approximately one minute and only required one attempt with Max who had the most prominent symptoms of ADHD of all of the participants. Therefore, the revised calibration procedure can be used with participants who have ADHD.

The success of the calibration process revealed differences in the eye movement behaviours between the participants with and without ADHD that were considerable and quite distinctive. Specifically the eye movements for the participants with ADHD were characterised by rapidly changing lines of gaze and short fixation periods (see section 3.5 for detailed results).

3.4 Session 2

A second session followed S1 to further investigate the patterns in the behavioural variables observed and to explore any effects of MPH on the behavioural variables.

3.4.1 Participants

Max, Andrew, John, Jason and Mike (see section 3.1 for a detailed profile of these participants) completed session 2 (S2)

3.4.2 Procedure

The main purpose of S2 was to investigate whether MPH had any affect on the behavioural variables outlined in section 2.5. The modified calibration procedure described in section 3.3.2 was followed. As in Experiment 1, the general experimental procedure in section section 2.7 was followed, however, Max took his usual morning dose of MPH and Andrew did not. Thus prior to S2 the participants with ADHD were randomly assigned to either take their usual morning dose of MPH prior to S2 and Experiment 2 or after the session was completed. The parents/caregivers of the participants were informed by phone a week prior to the session as to which group their child was randomly assigned and the time of their session. They were instructed to bring their child's usual dose of MPH to the session and that it would be given to their child immediately following the session. They were informed that a research assistant would be available to supervise the participant for 1 hr 30 min, until the medication took full effect. The participant that was not required to have his morning dose of MPH until after the session was scheduled to be the first participant of the day, followed by the participant taking MPH and then the two control participants. The participants' parents/caregivers were contacted by phone the day before S2 began to remind them whether their child should or should not take their morning dose of MPH. Their adherence to these requirements was confirmed before the session began.

3.5 Results and Discussion (Experiment 1)

In summary, the results of Experiment 1 support a number of the hypotheses outlined in section 1.5. The participants with ADHD did appear to have different eye movement behaviours than the matched controls. Specifically, their eye movement behaviour could be characterised by rapidly changing lines of gaze and shorter fixation periods for both reading aloud and silently. These differences corresponded with the symptoms of ADHD, as evidenced by the CTRS-R and the CPRS-R, in all cases. Of particular interest is that the eye movement behaviours of Jason resembled the matched controls more than they did the participants with ADHD, and these results tentatively agree with the obtained results of the CTRS-R and the CPRS-R and may indicate that he does not have ADHD, as diagnosed by his paediatrician. Therefore, these preliminary results suggest that further investigation into developing eye tracker technology as a diagnostic measure for ADHD is warranted.

The results of Experiment 1 also support the hypothesis that different eye movement behaviours would be observed for all participants when reading aloud, when compared to silent reading, and that these differences were more pronounced for participants with ADHD.

The research found that there was a relationship between the pattern of eye movements and the level of motor activity of the participants who had ADHD, but that this was not consistently exhibited. The results indicate that methylphenidate (MPH) reduced the percentage of arm and leg movement for Max, but did not result in noticeable reductions in the rapidity with which his eyes changed their line of gaze.

The eye movement behaviours observed were similar for all of the stories, therefore only the first story read aloud and the first story read silently are discussed in detail. The representativeness of these generalisations was checked and any atypicalities observed discussed. For detailed profiles of the participants refer to section 3.1.2.

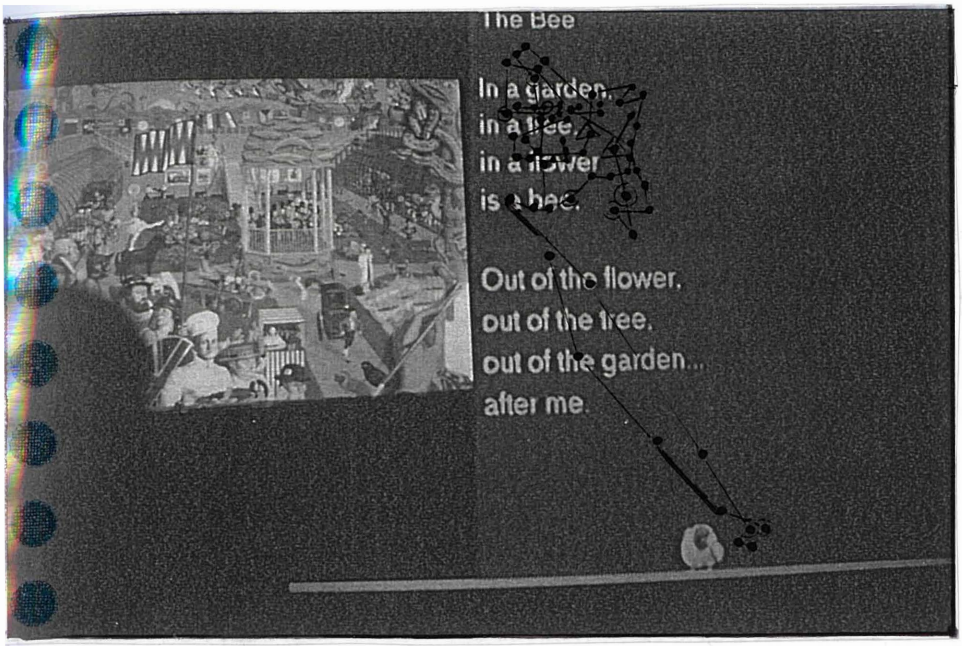
3.5.1 Max

Max had a diagnosis of ADHD. He attended the sessions on his own and said he was happy to do this.

Session 1 (S1): When presented with the first story for S1, Max took 21 seconds before he began reading aloud. Figure 3.5.1 shows that during this time his eyes moved around the stimuli rapidly, using large angles of saccades with no apparent pattern to the eye scanning movements. During this time Max only focused on the text five times for an interval between 250-500 ms, with the remainder of the fixation periods being less than this.

Figure 3.5.1. Eye movements for Max before he began reading aloud, S1.

Figure 3.5.2 shows that even when Max began reading aloud his eye scanning behaviour continued to change fixation points rapidly with little obvious pattern. Although, he did scan two words in the second and third lines sequentially, from right to left and then returned, after looking away, to scan the words again. Figure 3.5.2 shows that when Max was scanning the text and the area around the text he used smaller angles of saccades than when he scanned to the bottom of the page.



The Bee

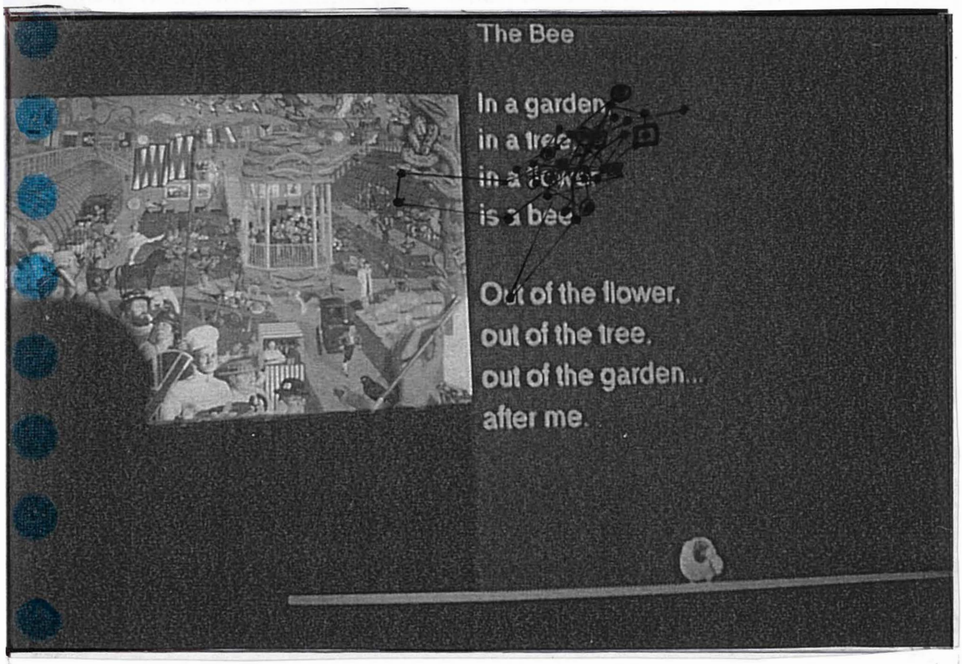
In a garden,
in a tree,
in a flower
is a bee.

Out of the flower,
out of the tree,
out of the garden...
after me.

Figure 3.5.2. Eye movements for Max when reading aloud, S1.

KEY:

- • 0< 250 ms
- ⊙ 250< 500 ms
- △ 500< 750 ms
- ⊡ 750<1000 ms

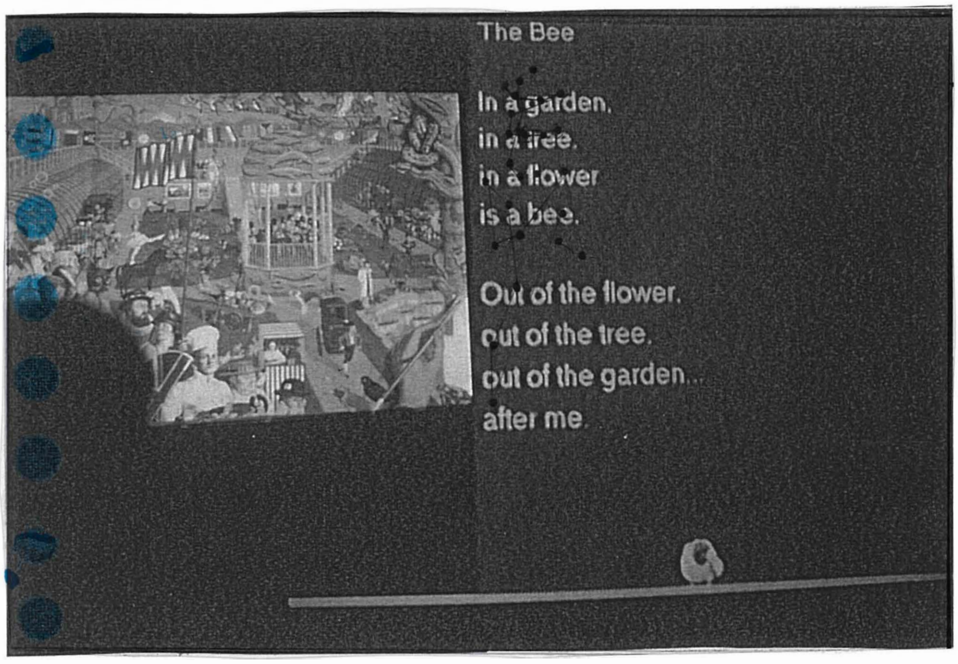


The Bee

In a garden,
in a tree,
in a flower
is a bee.

Out of the flower,
out of the tree,
out of the garden...
after me.

Figure 3.5.3. Eye movements for John when reading aloud, S1.



The Bee

In a garden,
in a tree,
in a flower
is a bee.

Out of the flower,
out of the tree,
out of the garden...
after me.

Figure 3.5.4. Eye movements for Andrew when reading aloud, S1.

Table 3.5.1 shows that for the stories Max read aloud, he only looked at the text, on average, 54% of the time. He spent a considerably large percentage of the time, 33%, looking at the "other" areas of the stimuli and, 9% and 4% of the time, looking at the picture and sheep distracters respectively. Table 3.5.1 shows that the mean number of words read per minute for the stories read aloud was, 16 and Max answered the comprehension questions with an accuracy of 50%.

Max only read half of the required story silently as the continuous monitoring of his eye movements during the first 68 seconds indicated that he was not reading the text at all, so he was instructed to read the story aloud. However, from analysis of the time he did read silently, there was a noticeable change in scanning behaviour compared to when reading aloud. Figure 3.5.5 shows that the rapidly changing eye movements covered a larger area of the stimuli and he used larger angles of saccades than when reading aloud (Figure 3.5.2.). Figure 3.5.5 shows that Max did not tend to fixate for longer than 250 ms on any portion of the presented stimuli and only fixated on the text twice, for a period between 250-500 ms.

Table 3.5.1 indicates that Max spent considerably less time looking at the text, 36%, when silent reading compared to reading aloud, and spent more time looking at the "other" areas of the stimuli, 47%. Table 3.5.1 also shows that Max spent 14% of the time looking at the picture distracter, slightly more than when reading aloud, but looked at the sheep for a similar percentage of the time, 3%. Although Max spent a considerable percentage of the time scanning the picture distracters he only correctly identified one of them presented in S1, therefore it may be possible that he was not processing this visual information. Table 3.5.1 also shows that the average number of words Max read silently was, 16.19. Given that he completed reading this story aloud it is not surprising that this is similar to the rate observed when reading aloud. Max answered the comprehension questions with 100% accuracy, which is quite remarkable given the variability of his eye movements when reading silently (Figure 3.5.5).

Table 3.5.1

Percentage of Time Looking at each Area of the Presented Text, the Mean Number of Words Read Per Minute and the Percentage of Correct answers for the Comprehension Questions and Identification of the Picture Distracters Presented for all the Participants in Experiment 1.

	Percentage of time looking in each area				Words Read Per Minute		Comprehension Questions	Identification of Picture Distracters	
	Text	Picture	Sheep	Other	M	SD	% Correct	% Correct Hits	% Correct Misses
MAX									
Session 1								50	100
Aloud	53.58	9.15	4.02	33.31	16.00	1.64	50		
Silent	35.94	14.06	0.71	46.88	16.19	-	100		
Session 2								100	100
Aloud	82.49	12.74	3.51	2.28	12.53	1.21	75		
Silent	58.02	18.03	14.98	8.98	58.49	7.24	50		
JOHN									
Session 1								0	83
Aloud	84.5	7.50	2.78	5.00	65.20	6.88	88		
Silent	94.75	0	0.71	4.55	57.55	4.18	100		
Session 2								50	100
Aloud	94.34	7.06	1.75	0	52.35	1.97	100		
Silent	98.24	1.18	0.59	0	53.85	8.56	100		
ANDREW									
Session 1								50	100
Aloud	89.49	1.99	1.79	6.75	29.22	-	50		
Silent	85.45	12.21	0	8.51	42.73	9.41	88		
Session 2								100	100
Aloud	66.12	2.00	0	31.90	31.96	9.04	75		
Silent	71.05	13.45	0	25.73	40.98	3.11	75		
JASON									
Session 1								0	100
Aloud	78.11	5.29	0.61	32.05	65.60	3.03	75		
Silent	64.53	13.72	0.6	21.15	75.58	3.87	100		
Session 2								100	100
Aloud	87.90	7.32	0.73	4.06	81.88	4.36	63		
Silent	78.69	11.25	0.36	9.68	90.31	10.18	88		
MIKE									
Session 1								50	100
Aloud	86.84	3.00	1.00	9.17	82.26	3.10	100		
Silent	91.69	2.5	1.62	3.73	90.10	15.75	50		
Session 2								100	100
Aloud	93.46	5.32	0	1.23	69.85	3.11	75		
Silent	84.55	9.26	1.38	4.78	78.47	0.11	88		

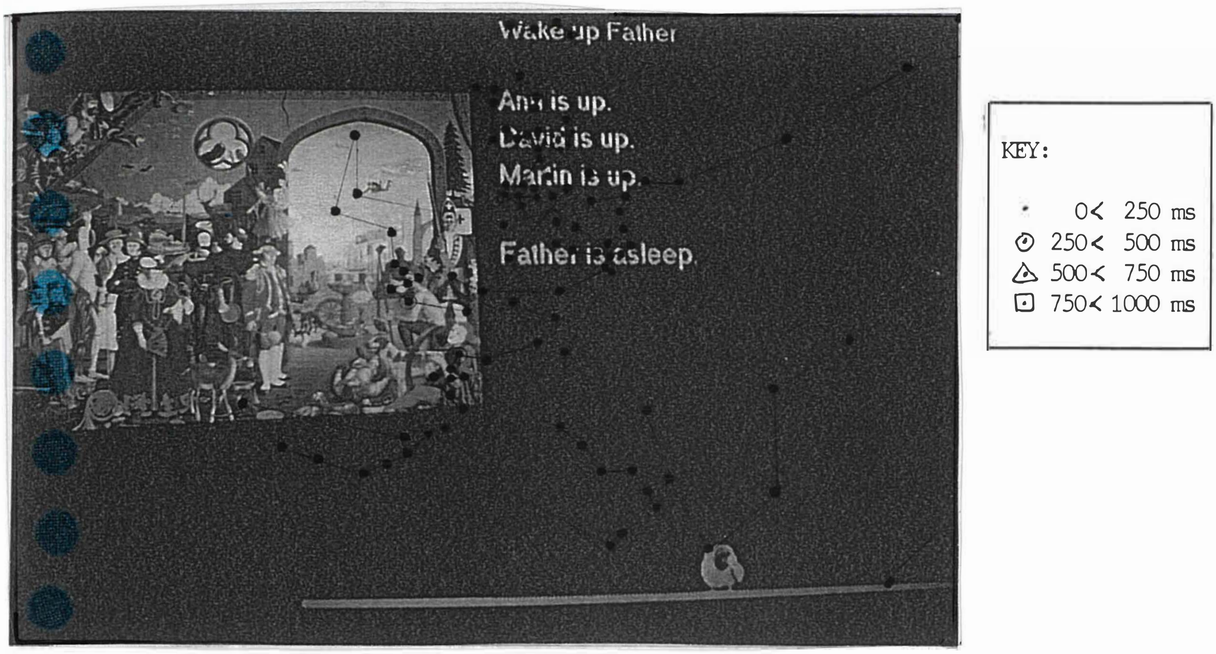


Figure 3.5.5. Eye movements for Max when silent reading, S1.

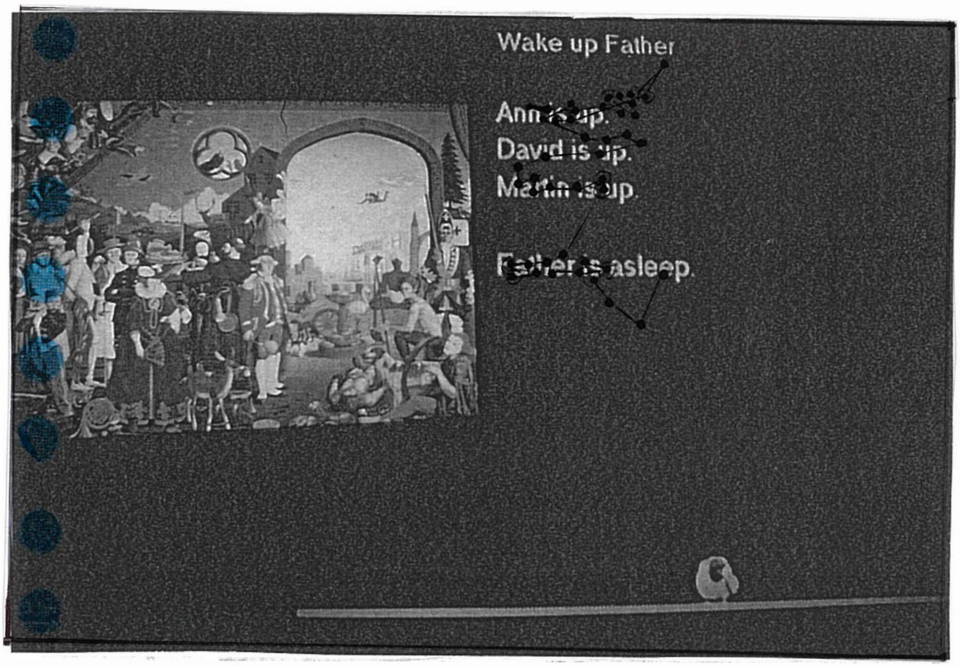


Figure 3.5.6. Eye movements for John when silent reading, S1.

Figure 3.5.21 shows that there was a considerable difference between the mean number of leg movements per minute for the stories that Max read aloud, 27, and silently, 41. However, the standard deviation for the mean number of leg movements per minute when reading silently was noticeably higher than observed for any other participant. The cumulative angles of his arm movements for the first story read aloud, was 3451 for a trial duration of 1 min 53 s, which was considerably less than when reading the first story silently, 8412 for a trial duration of 5 min 11 s. Therefore, when reading silently Max moved his arms and legs more than when reading aloud, although it is important to note that he took noticeably longer to read silently. It is interesting to note the similarity between the increased leg movement and the variability in places Max fixated when he was silent reading. It may be possible that both increased during off task behaviour.

Session 2 (S2): Max was randomly assigned to read the first two stories silently and the second two aloud which was in the reverse order to S1. However, the main difference between S1 and S2 for Max was that he had taken his MPH medication approximately 1.5 hours prior to S2. This resulted in a number of differences in the behavioural variables.

Figure 3.5.7 illustrates that Max's eye movements whilst reading the first story silently shows similar rapidly changing eye movements with larger angles of saccades as observed in S1 (Figure 3.5.5). However, he fixated on the text five times for a duration of between 250-500 ms, which is over twice that observed in S1.

Table 3.5.1 shows that there was a noticeable increase in the percentage of time Max looked at the text during S2 whilst silent reading 58%, which may indicate that his ability to focus on the required area improved slightly after administration of MPH. However, whether the increase in the time spent viewing the text resulted in an increase in information processing is questionable as Table 3.5.1 shows that he answered the comprehension questions with the same accuracy as in S1, 50%. Whether Max actually read any of the text silently is debatable as the video analysis of his eye movements revealed that he said he had finished reading before he had looked at the majority of the text. This is the most likely explanation for the dramatic improvement in the mean number of words read per minute for silent reading, 58, for S2.

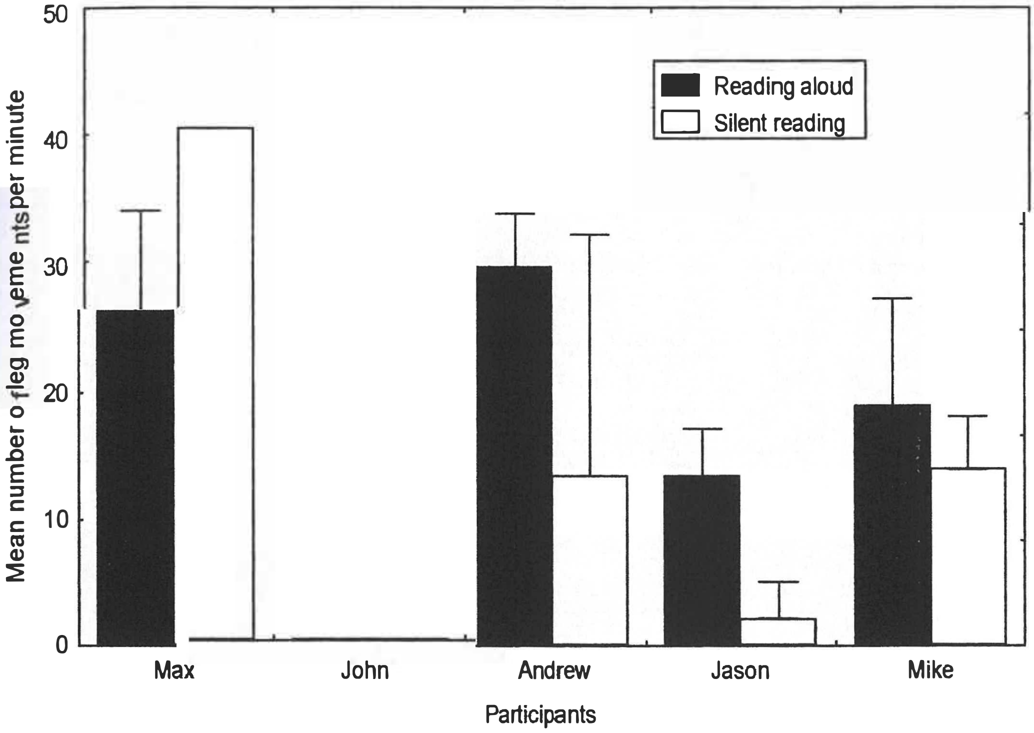


Figure 3 5.21 Mean number of leg movements per minute for each participant when reading aloud and silently, Session 1.

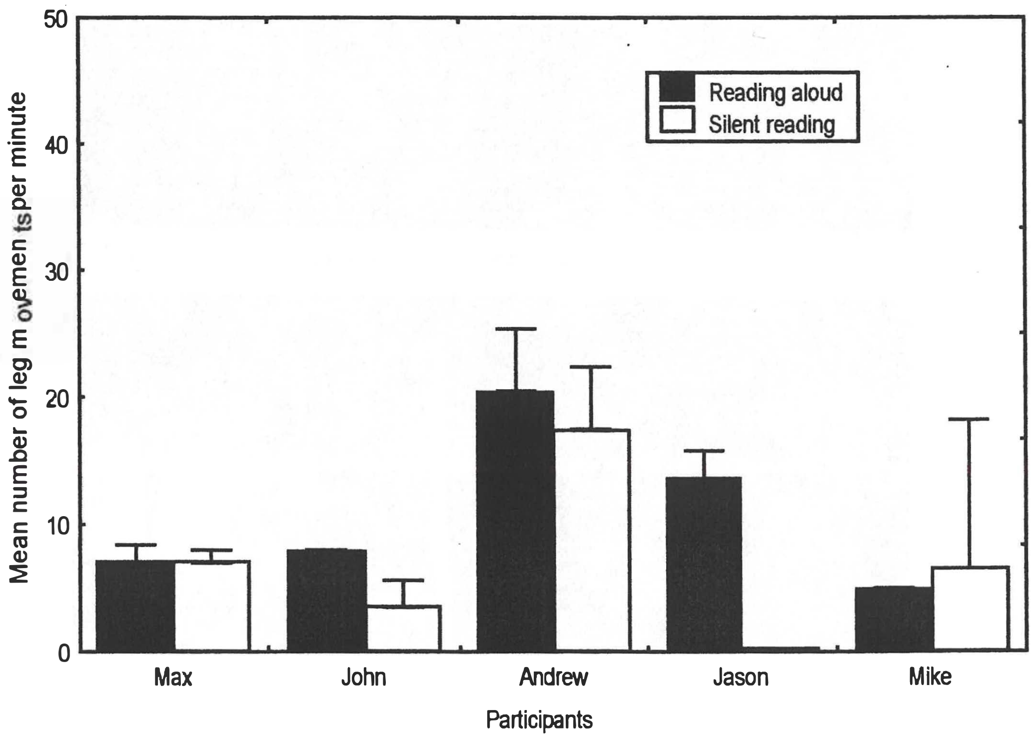


Figure 3.5.22 Mean number of leg movments per minute for each participant when reading aloud and silently, Session 2.

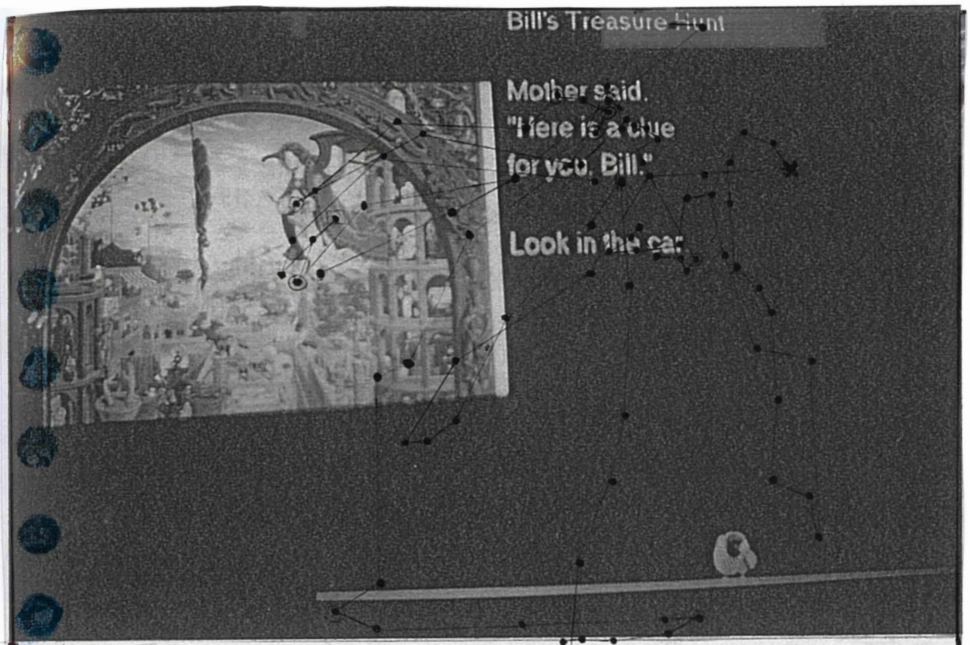


Figure 3.5.7 Eye movements for Max when silent reading, S2.

KEY:

• 0< 250 ms
⊙ 250< 500 ms
△ 500< 750 ms
◻ 750< 1000 ms

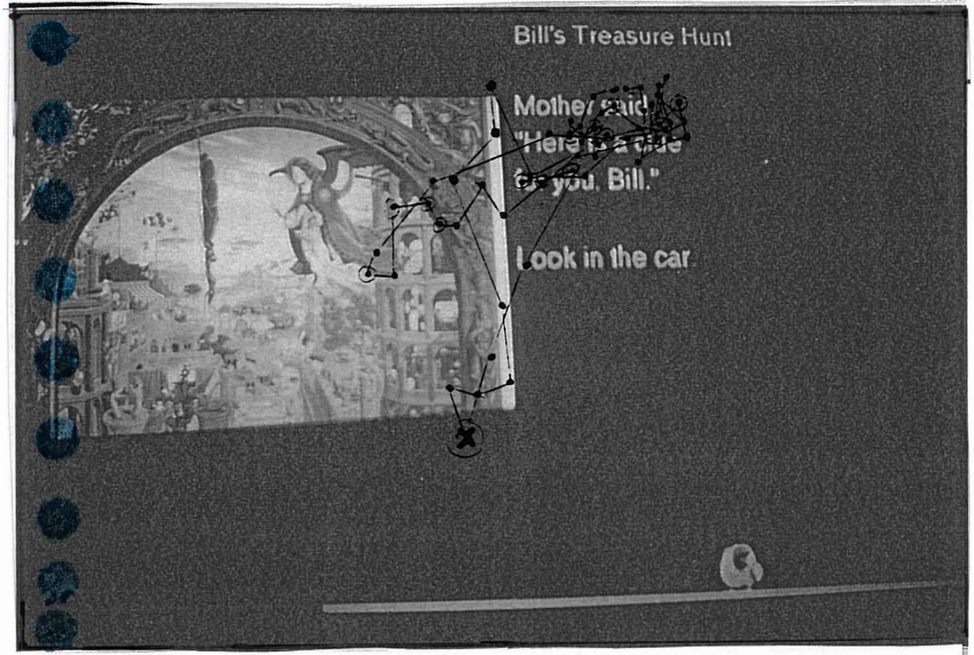


Figure 3.5.8. Eye movements for John when reading aloud, S2.

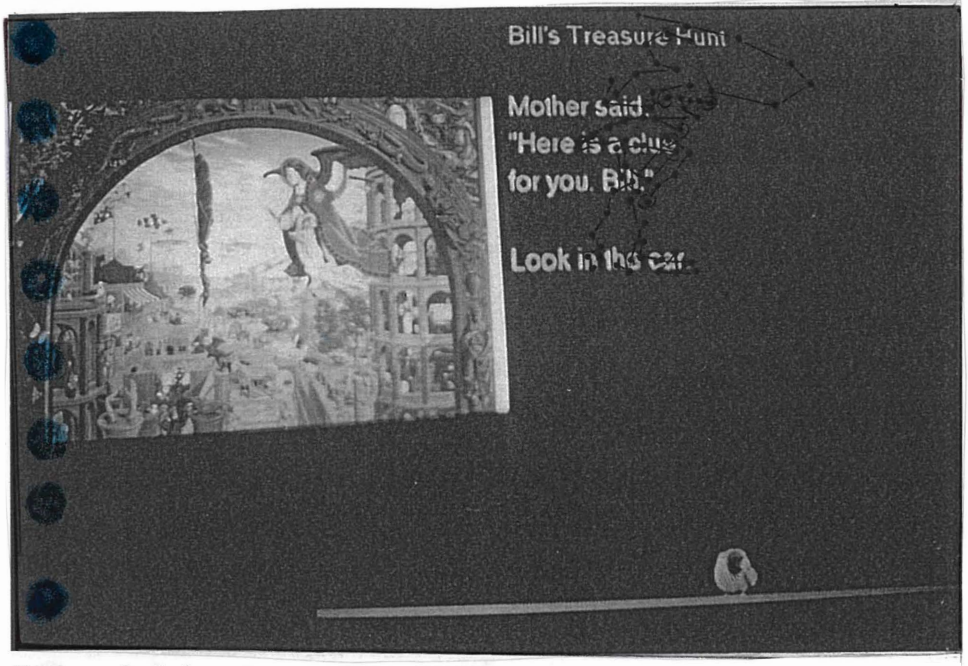


Figure 3.5.9. Eye movements for Andrew when reading aloud, S2.

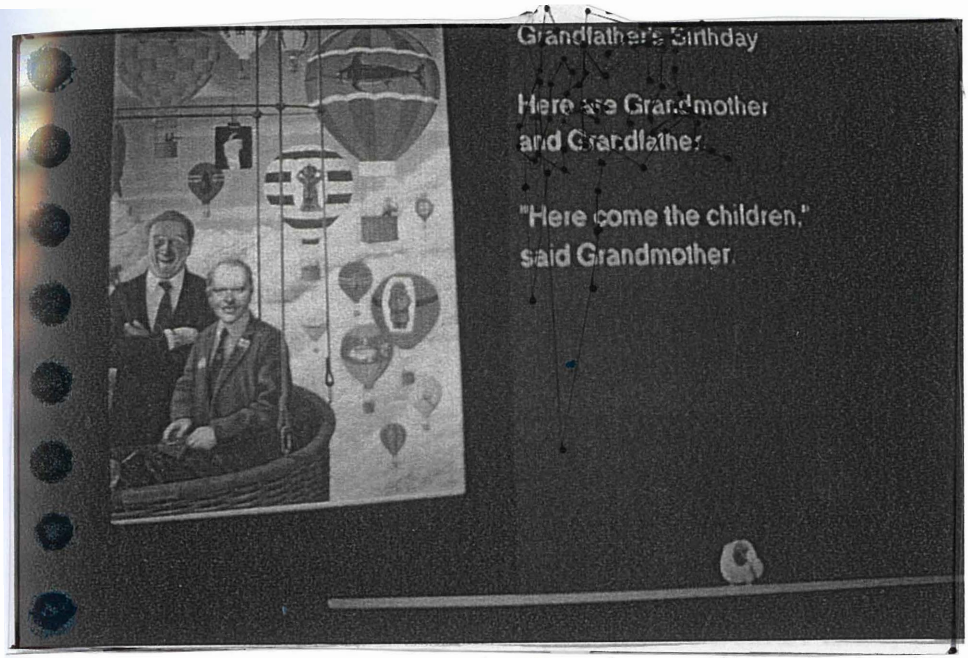
Table 3.5.1 shows that there was a considerable reduction in the percentage of time Max spent looking at the "other" areas of the stimuli, 9%, compared to S1. However, the percentage of time spent looking at the sheep and the picture distracters increased to, 18% and 15%, respectively. Max identified the picture distracters displayed and not displayed with an accuracy of 100%, therefore one can tentatively conclude that he was processing the visual information when looking for a longer duration at the distracters.

Comparatively, Max's eye scanning behaviour when reading aloud was similar for S1 and S2, although he began reading after 4 s, which was a noticeable improvement compared to S1. Figure 3.5.10 shows that the majority of the eye movements focusing on the words are interspersed with looking at the area between the text. However, this trend improved for the remainder of the stories he read aloud as the percentage of time spent looking at the text increased noticeably to 82%, as shown in Table 3.5.1. Figure 3.5.10 illustrates that he focused on the text for a period of 250-500 ms four times, which was a noticeable improvement compared to S1. Figure 3.5.10 illustrates a slight increase in the amount of sequential scanning along words from left to right compared to S1, for example the word "Grandfather" in the title and in the text.

Table 3.5.1 shows that the mean number of words read aloud was 12.53, slightly less than S1. There was an increase in Max's level of comprehension of the stories read aloud in S2, to an accuracy of 75%. Similar to the pattern observed for silent reading in S1, there was a considerable decrease in the percentage of time looking at the "other" areas of the stimuli, 2%. However, Table 3.5.1 shows that the percentage of time looking at the picture distracters increased slightly, 13%, whereas the percentage of time spent looking at the sheep remained relatively the same, 4%. It was difficult to determine if one of the reasons Max looked away from particular words was that he found that word difficult to read. This is possible as he often returned to the word unprompted and read the word accurately. Thus, perhaps he processed the word when looking away or perhaps he was scanning the other words and surrounding stimuli for clues for the word. Indeed, it was observed in both sessions that he often self corrected his mistakes without prompting from the researcher.

KEY:

• 0< 250 ms
⊙ 250< 500 ms
△ 500< 750 ms
⊡ 750< 1000 ms

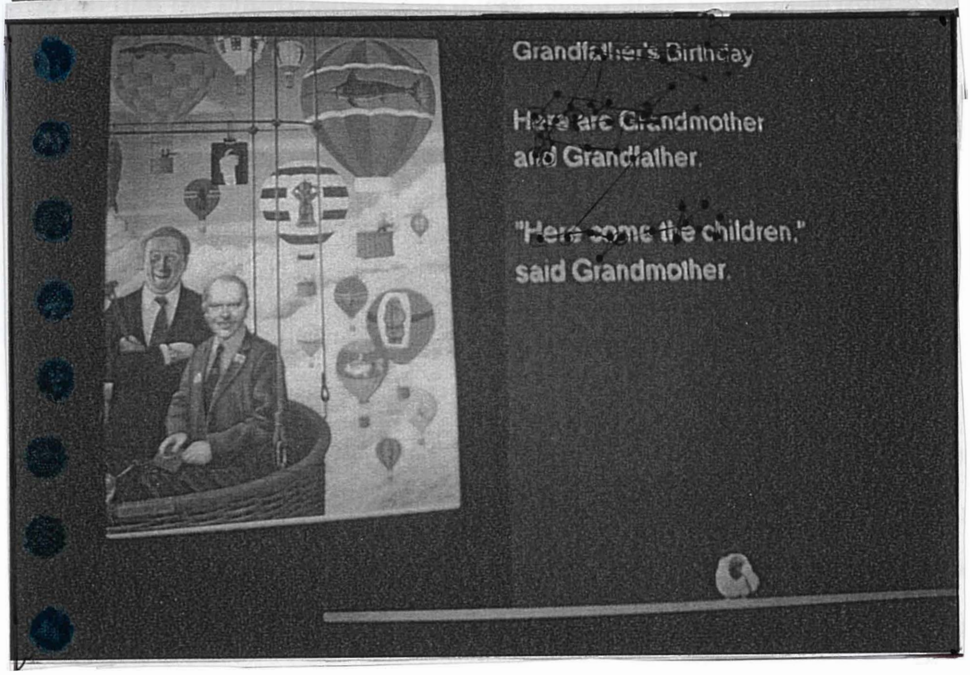


Grandfather's Birthday

Here are Grandmother
and Grandfather.

"Here come the children,"
said Grandmother.

Figure 3.5.10. Eye movements for Max when reading aloud, S2.

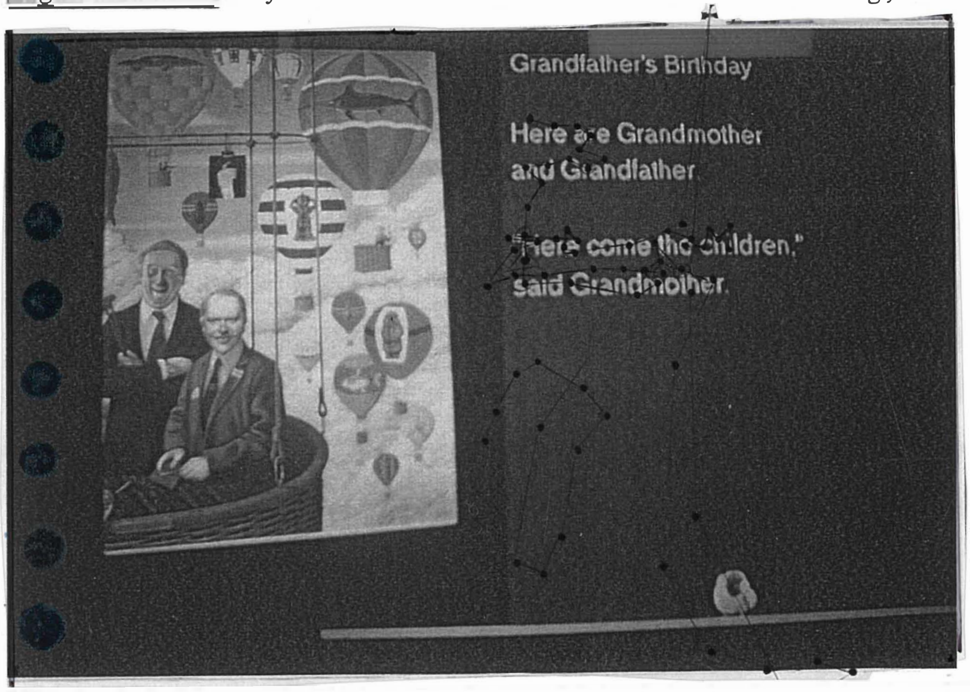


Grandfather's Birthday

Here are Grandmother
and Grandfather.

"Here come the children,"
said Grandmother.

Figure 3.5.11. Eye movements for John when silent reading, S2.



Grandfather's Birthday

Here are Grandmother
and Grandfather.

"Here come the children,"
said Grandmother.

Figure 3.5.12. Eye movements for Andrew when silent reading, S2.

There was a considerable decrease in the mean number of leg movements per minute for the stories read aloud, 14, as shown in Figure 3.5.22, and in the cumulative angles of arm movements for the first story, 285 deg for a trial duration of 6 min 15 s, compared with S1. There was also a considerable decrease in the mean number of leg movements per minute when reading silently, 7 as shown in Figure 3.5.24, and in the arm movements, 814 deg for a duration of 1 min 29 s, compared to S1.

The order with which Max read either aloud or silently first was changed from S1 to S2. Whilst it cannot be ruled out that the order of presentation may have played a part in improving Max's performance from S1 to S2, this is unlikely given that the improvement was not reflected in all of the behavioural variables.

3.5.2 John

John was the matched control for Max and Andrew and did not have a diagnosis of ADHD. John's foster mother accompanied him for S1 and his foster father accompanied him for S2.

Session 1: John began reading the text aloud immediately and, unlike Max or Andrew, had finished reading the paragraph presented in Figure 3.5.2 within 10 seconds. This was a stark contrast observed in the on-task behaviour between the participants with ADHD and their matched control. As Figure 3.5.2 illustrates, John's eye movements centred around the text with eight instances of focusing on the text for period between 250-500 ms, and two instances of focusing lasting between 750-1000 ms. John's change in fixation points remained within the words of the line he was reading, and he tended to look about the word, but not in a sequential manner as later described for Jason (section 3.5.4) or Mike (section 3.5.5). This may be a difference in scanning patterns that is related to their different reading levels. Analysis of the eye movement video indicated that the times that John looked away from the text, as illustrated in Figure 3.5.3, were when he could not read the word in question. Table 3.5.1 shows that he did not identifying seeing any of the picture distracters presented and was only 83% accurate in identfying the pictures he did not see. Therefore one can tentatively conclude that he did not process the visual information of the picture distracters when looking at them.

Table 3.5.1 shows that the percentage of time John spent looking at the text when reading aloud was 85%, which was considerably higher than the percentage observed for Max. John looked at the "other" areas of the stimuli, 5% of the time, which was considerably lower than Max. Alternatively, Table 3.5.1 shows that the percentage of time John looked at the picture distracters, 8%, and the sheep, 3%, was similar to Max. The mean number of words John read per minute when reading aloud was 65.20. The percentage with which he answered the comprehension questions accurately was 88%.

Figure 3.5.6 shows that John adopted a more structured approach to scanning the text when silent reading. Specifically, he generally scanned each word in each line then moved on to the beginning of the next line sequentially, with limited time focusing on anything other than the text. Table 3.5.1 shows that this pattern continued with the rest of the stories as the percentage of time spent looking at the text was 95%, 5% for looking at the "other" places, and 1% and 0% for looking at the sheep and picture distracters respectively. Given that he did not look at the picture distracters, it is not surprising that he did not correctly identify the picture distracters shown, however he did identify the pictures he did not see with 100% accuracy, as illustrated in Table 3.5.1.

Table 3.5.1 shows that the mean number of words John read silently per minute was 75.58, slightly faster than when reading aloud. The percentage with which he answered the comprehension questions accurately was 100%.

Figure 3.5.21 show that John did not move his legs at all whilst reading during S1. John only moved his arms slightly when reading the first story aloud, with the cumulative angles of arm movements being 17 deg, for a trial duration of 1 min 30 s.

Session 2: There was a noticeable consistency in John's scanning patterns between S1 and S2. One of the main differences between Max and John, was that with John there was a logical pattern of eye movement behaviour that could be described for both sessions. For example, Figure 3.5.8 illustrates that John only focused briefly on the first two words, as he was able to read them easily, whereas when reading the second line he focused on the first two words with three fixation periods lasting between 250-500 ms, as he had difficulty reading them. This reading strategy was evident in the other stories he read, therefore it appears that when John finds a word difficult, one strategy he adopts is to fixate on it for longer periods. Often when reading, John scanned the words and lines forwards and then backwards, as evidenced in Figure 3.5.8 for the line "Here is a clue." Figure 3.5.8 shows that John stopped reading when he got to the word "clue" and looked at the distracter twice, returning to the word each time, before he was told what the word was. Looking away when a word was difficult was a pattern observed in S1, therefore this may be another reading strategy he employs. This could be related to the fact that in the "whole language" approach to teaching reading, the learner is encouraged to look at the pictures to try and determine what word fits into the sentence in question (Clay, 1987).

Consistent with the findings from S1, John's eye movement behaviours observed when reading silently follow a more structured pattern. Figure 3.5.11 shows that basically John focused on each line of the text from the top to the bottom of the page, and periodically re-scanned words. Figure 3.5.11 shows that he focused on the text nine times for an interval between 250-500 ms.

Table 3.5.1 indicates that the percentage of time John looked at the text when reading aloud and silently were similar in value, 94% and 98% respectively, again with him focusing slightly more on the text when silent reading, as observed in S1. Table 3.5.1 also shows that there was little difference in the percentage of time he looked at the picture distracters and the sheep compared to S1 when reading aloud, 7%, and 2% respectively, and 1% for both distracters when reading silently. John did not look at the "other" parts of the presented stimuli, which was a noticeable decrease compared to S1. The mean number of words John read per minute decreased slightly during S2, for both the aloud and silent reading categories, 52.35 and 53.10 respectively, but are noteably consistent with each other. John answered the comprehension questions with 100% accuracy both after reading aloud and silently, which again was consistent with S1.

Figure 3.5.22 shows that during S2 John did move his legs slightly, with a mean number of leg movements per minute when reading aloud of 8, and when reading silently of 4. However, he did not move his arms at all during S2.

During both sessions it was observed that John adopted a more organised approach than when reading aloud. A possible explanation for this is that when reading silently there is no performance measure that adds pressure to read each word accurately before proceeding. Perhaps this reflects an element of performance anxiety as he was reading aloud in the presence of three researchers and a foster parent.

3.5.3 Andrew

Andrew had a diagnosis of ADHD. Andrew's mother and sister accompanied him for half of S1 and S2, and his brother remained for all of S1 and S2. Prior to reading the first story silently, Andrew moved the scene camera, thus, there was no eye scanning data available for analysis. This incident is not surprising given the percentage of arm and leg movement observed during Experiment 1.

Session 1: Like Max, Andrew took a long time before he began reading the first story aloud and his eye movement patterns during this time resembled Max's (see section 3.5.1), in that they covered a large area of the stimuli using large angles of saccades, with rapidly changing fixation points. Figure 3.5.4 illustrates Andrew's eye movement behaviour once he began reading aloud and indicate that, although Andrew did not look at the distracters, he spent a considerable percentage of time focusing on the areas between the text and fixated there nine times, for a period between 250-500 ms. This pattern was different to Max, who generally did not focus in any area for 250 ms or more. Figure 3.5.4 illustrates that Andrew's line of gaze changed rapidly like Max's (see Figure 3.5.2). There was some evidence that he did scan over words in each line sequentially but the scanning was in no set order as described for John (see section 3.5.2). Andrew did not focus on all of the words in each line he read aloud in Figure 3.5.4, yet he was able to read them all accurately.

Table 3.5.1 shows that Andrew looked at the text a similar percentage of the time when reading aloud, 89%, compared to silently, 85%. The percentage of time that he looked at the picture distracters was less when reading aloud, 2%, compared to silently, 12%. However, Table 3.5.1 shows that he only correctly identified 50% of the distracters shown, but correctly identified the pictures not presented with 100% accuracy. He rarely looked at the sheep, 2% when reading aloud, and not at all when reading silently. Andrew looked at the "other" areas of the presented stimuli a similar percentage when reading aloud and silently, 7% and 9%, respectively. Table 5.1.2 also shows that his reading speed was 29.22, when reading aloud, and 42.73 when reading silently. During the data collection it was hypothesised that this increase in reading speed was due to the fact that he was only briefly looking at the words and then saying he was finished when he had not, as hypothesised with Max (see section 3.5.1). However, it is unlikely that was the case for Andrew as the accuracy with which he answered the comprehension questions was greater when silent reading, 88%, compared to 50% when reading aloud.

Like Max, Andrew moved his arms and legs considerably more than observed for John. Figure 3.5.21 shows that Andrew's mean number of leg movements per minute when reading aloud was 30, and when reading silently was 27. The cumulative angles of his arm movements when reading aloud was, 79 deg for a duration of 57 s, and increased when silent reading to 209 deg, for a duration of 1 min 22 s. This increase in movement when reading silently was also observed in Max (section 3.5.1).

Session 2: Figure 3.5.9 illustrates that Andrew's eye movement behaviours in S2 resembled those observed in S1 in that they were characterised by frequent, rapid changes in the line of gaze, and that he did not fixate on the words at the beginning of the lines. As observed in S1 he spent a considerable percentage of time focusing on the areas between the text, but only fixated there twice for a period between 250-500ms. Whereas he only fixated on the text four times for a period between 250-500ms, which was similar to S1. Figure 3.5.9 shows that Andrew only sequentially fixated on the last words on each line, the order with which he fixated on the other words and re-focused on these words did not follow any noticeable pattern. However, this seemingly piecemeal approach to reading was effective in that he read the lines out loud accurately.

As mentioned previously, there was no data for the eye movements for silent reading in S1, but the eye movement behaviours analysed in S2 were considerably different than when Andrew was reading aloud. Figure 3.5.12 shows that the area which his line of gaze covered was noticeably larger, as was the average angle of saccades he used compared to Figure 3.5.4 or Figure 3.5.9. For the first two lines presented in Figure 3.5.12 his eye movements had a distinct pattern. For example, in the first sentence he sequentially focused from left to right, and on the second sentence he focused sequentially from right to left. However, for the last two sentences his eye movements were much more erratic. For example, after focusing on the word, “here,” for between 250-500 ms, he then sequentially focused on each word on the last line from left to right, then scanned around the length of the presented text before he scanned the last sentence from right to left, then sequentially focussed on each word of the third sentence. Thus, analysis of Andrew’s eye movement patterns did reveal a higher incidence of sequential scanning when silent reading than Max, but the majority of the scanning went from left to right which was opposite than observed for John. This may represent the typical waxing and waning attentional behaviour previously described for indviduals with ADHD (Pearson et al., 1995). However, if one reads what the words he scanned in order for the last two sentences were, “here,” “said grandmother,” “grandmother said,” “come the children,” the sense of the sentence is preserved. But such preservation of sense will not always be the case, so his scanning style may interfere with comprehension in other situations, particularly with more difficult text. Andrew, although more distracted than John, was able to redirect himself to the task at hand without any prompting from the researchers.

Table 3.5.1 shows that the percentage of time Andrew looked at the text whilst reading aloud decreased noticeably in S2 to 66%, and when silent reading, 71%. The percentage of time spent looking at the picture distracters was similar between S1 and S2 when reading aloud, 2%, silently, 13%, but he was able to identify the pictures he did and did not see with 100% accuracy. Table 3.5.1 shows that Andrew did not look at the sheep at all during S2, however the percentage of time he spent looking at the “other” areas of the stimuli presented increased noticeably for both reading aloud and silently, 32% and 26% respectively. Andrew’s reading speed remained fairly constant in S2, compared to S1, with the mean number of words read per minute when reading aloud being 31.96, and 40.98, when silent reading. Andrew’s accuracy for answering the comprehension questions increased slightly in S2 after reading aloud, 75%, but dropped slightly when silent reading, 75%, as shown on Table 3.5.1.

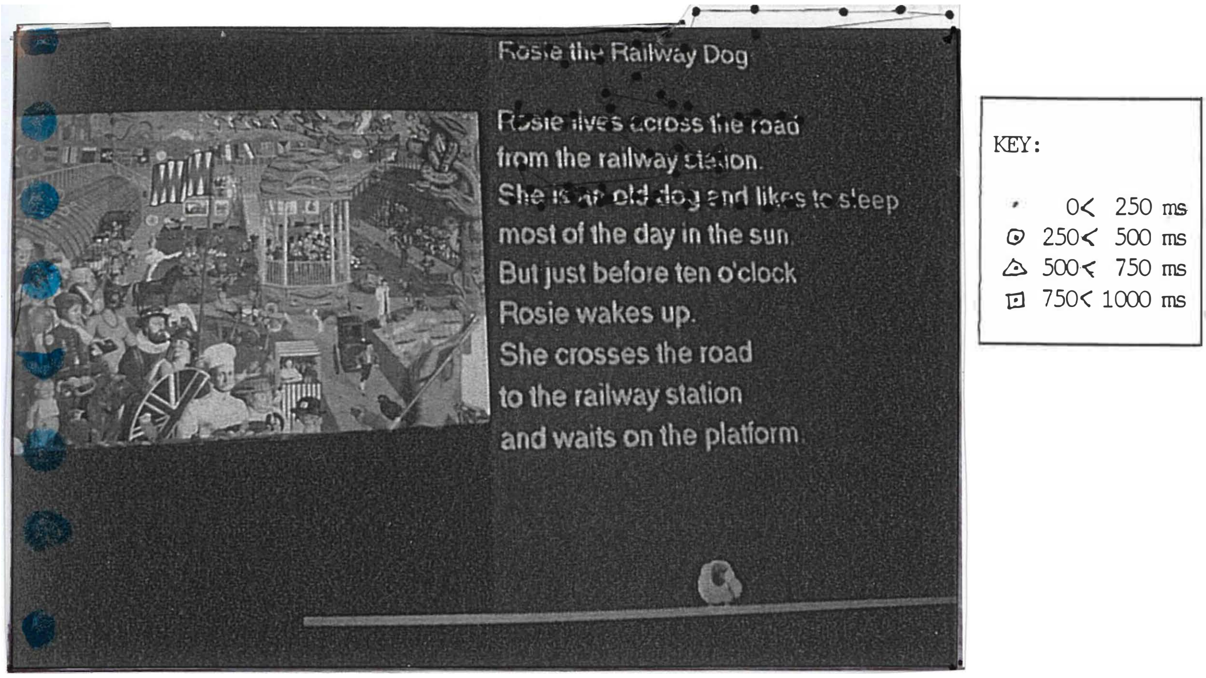
The mean number of leg movements per minute increased slightly compared to S1, but was not as marked as the decrease observed for Max after he had MPH (see section 3.5.1). Figure 3.5.22 shows that it was 21 when reading aloud, and 18 when reading silently. The cumulative angles of the arm movements for Andrew when reading the first story aloud was 184 deg, for a trial duration of 2 min 3 s, which was similar to S1. However, he did not move the steering wheel at all whilst reading the first story silently.

3.5.4 Jason

Although, Jason had been diagnosed with ADHD by a paediatrician, his obtained scores on the CTRS-T and CPRS-R did not support this diagnosis. Therefore, Jason remained a participant to see whether his reading patterns were more like the other participants with ADHD or more like his matched control, Mike. Jason attended the sessions on his own and was reportedly happy to do so.

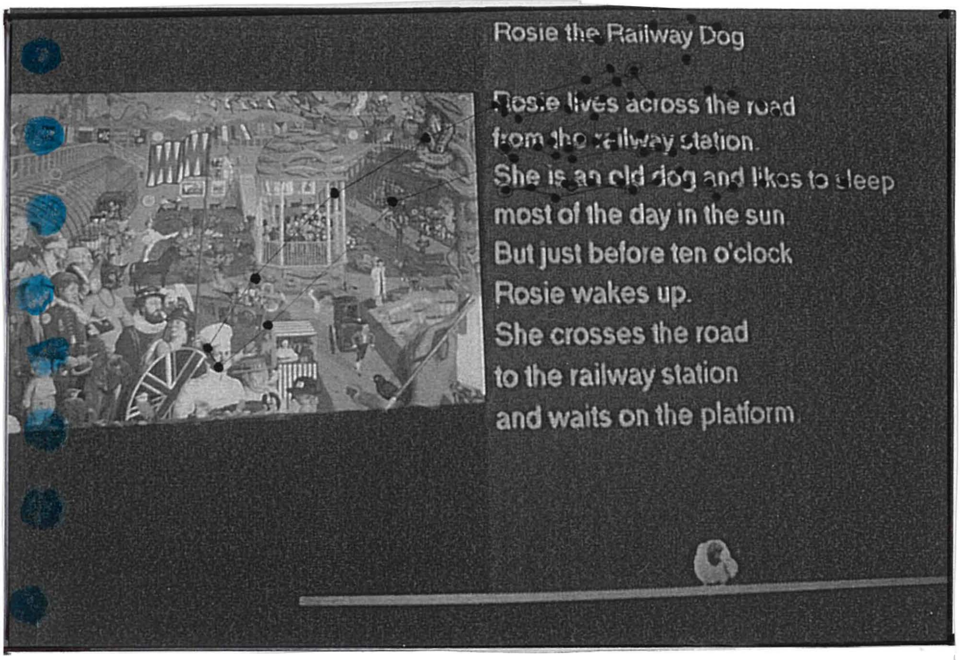
Session 1: Jason read the first story for S1 aloud, and like Max and Andrew took a while before he started reading, approximately 11 seconds. Figure 3.5.13 shows that even after he initially focused on the first word he took a while before his eye movements followed a general pattern, as he scanned the area above the presented stimuli using larger angles of saccades than observed when reading. Once he began reading, his lines of gaze followed a general pattern that involved scanning each sentence, forwards and backwards, before he read it aloud. For example, Figure 3.5.13 shows that for the first line he focused on the last three words from left to right, then scanned over each word to the beginning of the line and then again focused on the words from left to right. It appeared that he could remember the sentences accurately even though his order of eye movements varied considerably compared to Mike's as discussed in the next section. Alternatively, he scanned the last line from left to right then right to left for the first five words, but he read aloud as he went. Andrew focused on the text four times for an interval between 250-500 ms, and three times for an interval between 500-750 ms. Table 3.5.1 shows that Jason's mean number of words read per minute when reading aloud was, 65.60, and the percentage of correct answers to the comprehension questions was, 75%.

Figure 3.5.15 shows that when Jason was silent reading, the pattern of going from left to right then re-scanning the words from right to left continued. However, he was more likely to look at the area between the text or at other words before returning to the word in question. Figure 3.5.15 illustrates that he fixated on the text for a period between 250-500 ms, seven times, and between the


Rosie the Railway Dog

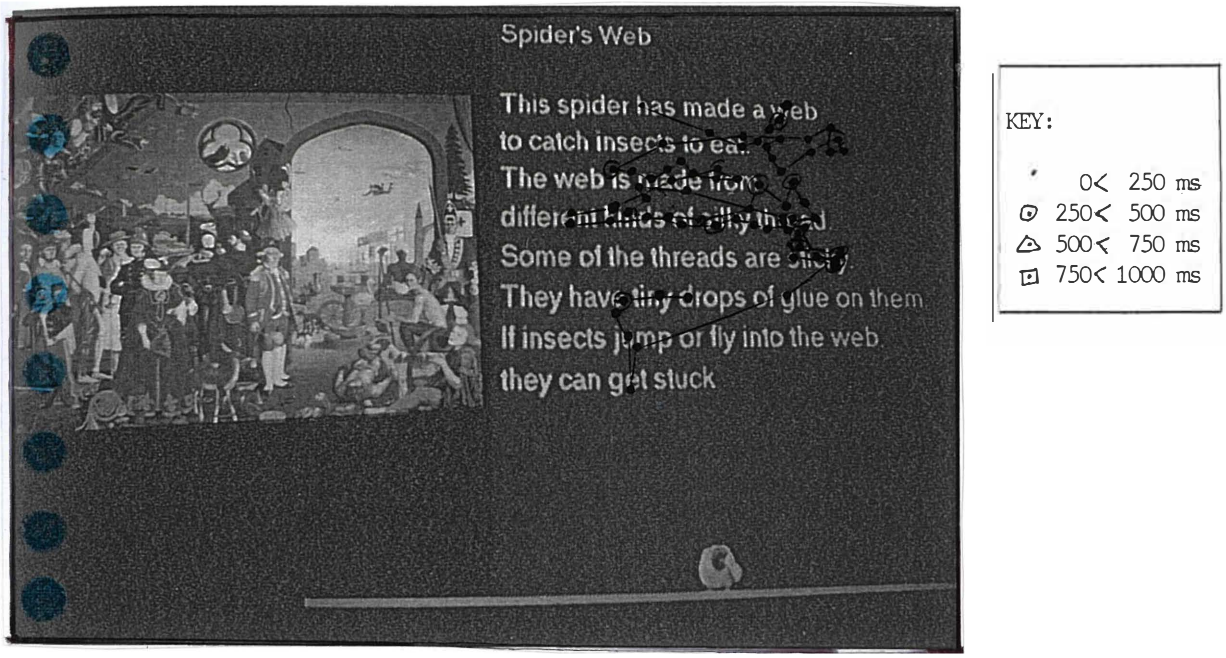
Rosie lives across the road
from the railway station.
She is an old dog and likes to sleep
most of the day in the sun.
But just before ten o'clock
Rosie wakes up.
She crosses the road
to the railway station
and waits on the platform.

Figure 3.5.13. Eye movements for Jason when reading aloud, S1.


Rosie the Railway Dog

Rosie lives across the road
from the railway station.
She is an old dog and likes to sleep
most of the day in the sun.
But just before ten o'clock
Rosie wakes up.
She crosses the road
to the railway station
and waits on the platform.

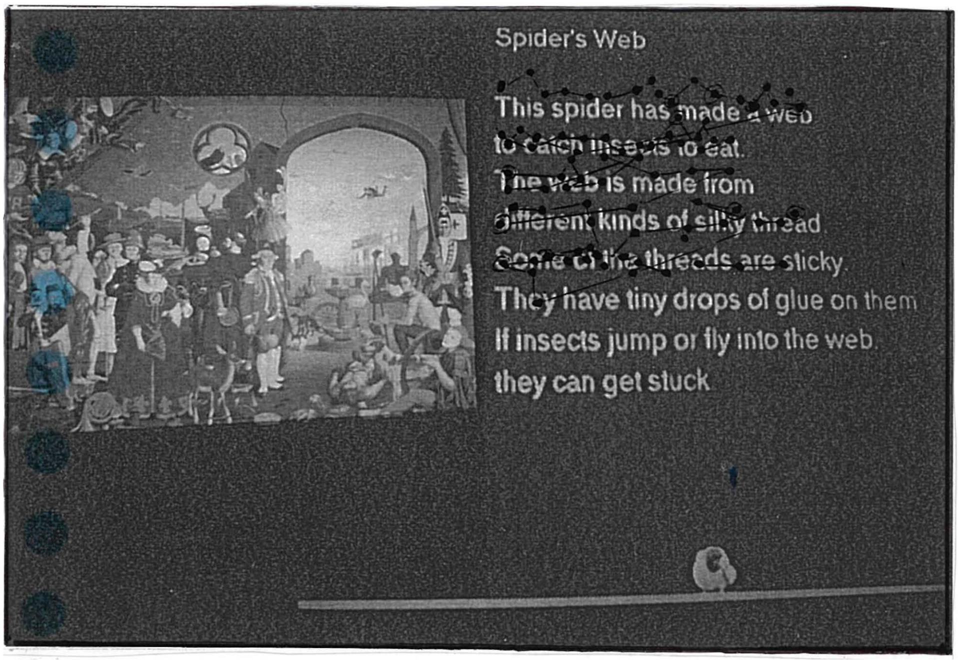
Figure 3.5.14. Eye movements for Mike when silent reading, S1.



Spider's Web

This spider has made a web
to catch insects to eat.
The web is made from
different kinds of silky thread
Some of the threads are sticky.
They have tiny drops of glue on them
If insects jump or fly into the web
they can get stuck

Figure 3.5.15. Eye movements for Jason when silent reading, S1.



Spider's Web

This spider has made a web
to catch insects to eat.
The web is made from
different kinds of silky thread
Some of the threads are sticky.
They have tiny drops of glue on them
If insects jump or fly into the web
they can get stuck

Figure 3.5.16. Eye movements for Mike when reading aloud, S1.

text five times for the same interval length. Figure 3.5.15 shows that Jason did not focus on the first words of the first three sentences, but for the words he did scan, the angle of the saccades were as small as they were when he was looking at the areas beside or between the texts. When silent reading, Jason was less likely to look at all of the words, but he was still comprehending what he read as he answered the comprehension questions with an accuracy of 100%, as shown on Table 3.5.1. However, Figure 3.5.15 shows that he scanned the words in each line erratically, for example, he only scanned the last two words of the fifth line, focused on the last two lines briefly and then focused on the second and third words of the sixth and seventh lines.

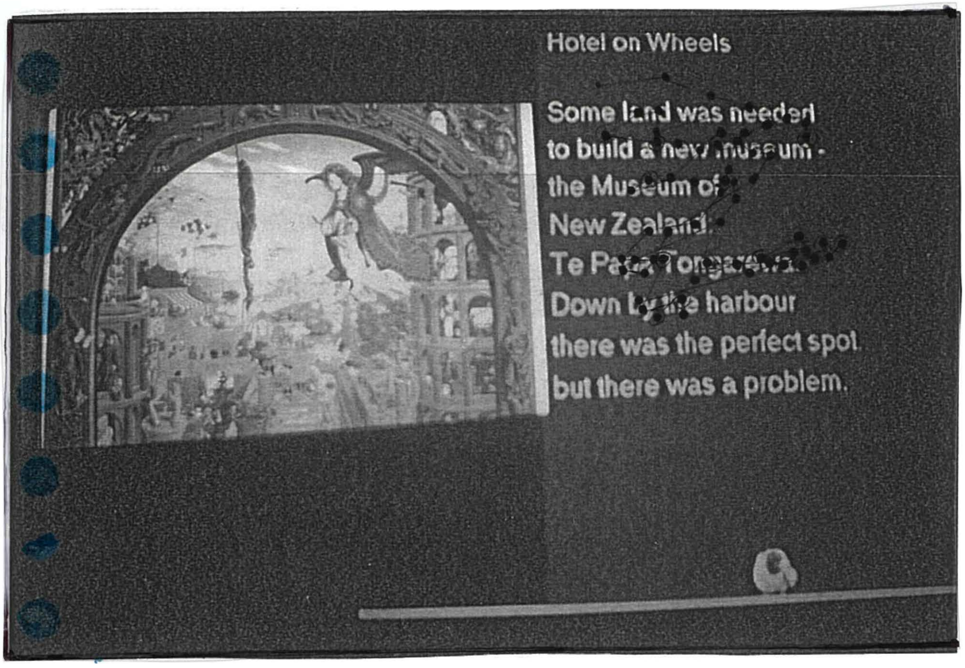
Table 3.5.1 shows that the percentage of time Jason looked at the text when reading aloud was 78%, and 65% when silent reading. Jason looked at the picture distracters 5% of the time when reading aloud, and 14% of the time when silent reading, but was not able identify any of the pictures presented during S1, although he correctly identified all of the pictures not shown. These results were similar to those found for John (see section 3.5.2), therefore, it is possible that even though he fixated on the pictures, he may not have been processing the information. Table 3.5.1 shows that Jason looked at the sheep the same percentage of time when reading aloud and silently, 1%. Jason looked at the "other" areas of the stimuli presented for a considerable percentage of the time, both when reading aloud, 32%, and when silent reading, 21%. Table 3.5.1 shows that Jason's mean number of words read per minute when silent reading was slightly faster, 75.58, than when reading aloud.

Figure 3.5.21 shows that Jason's mean number of leg movements per minute whilst reading aloud was, 13, but that he moved his legs less when reading silently. The cumulative angles of the arm movements for the first story Jason read aloud, 2632 deg for a duration of 3 min 15 s, was comparatively high, with Max being the only other participant that moved his arms more for a single trial.. However, Jason did not move the steering wheel when reading silently, but took 1 min 41 s, to read the first story silently.

Session 2: Jason read the first story for S2 aloud and he took considerably less time before he began reading the story aloud, 5 s, and 4 s when silent reading, compared to S1.

Figure 3.5.17 shows that for the first three lines he read aloud he focused on each word from left to right. Apart from the first line, he did not focus on any of the the first words, but he was still able to read these words accurately. It is possible that he was able to predict what these linking words were. For example, in the case of reading the words New Zealand, he only looked at Zealand, which is not surprising as Zealand is always preceded by New. Interestingly, after focusing on the word museum on the second line, he returned to this initial presentation when he came across the word museum in the third line, which was perhaps facilitated by a desire to check that it was the same word. Jason had difficulty reading the word "Papa," and as Figure 3.5.17 shows he redirected his focus to this word after receiving prompting from the researcher. This observed pattern of looking away from a difficult word was also observed in the other participants, most notably John (see section 3.5.2). Another strategy observed, was that Jason, like John, fixated on words he found difficult for extended periods of time. For example, Figure 3.5.17 shows that he focused on the middle of the word "Tongarewa," and then changed his focus to the first part of the word for one interval between 500-750 ms and then focused six times for a period of 250-500 ms, and once for a period of between 500-750 ms at the end of the word. Indeed, Figure 3.5.17 illustrates that for the first 10 seconds of reading aloud, he focused on the text for a period of 250-500 ms, a total of 15 times during S2, which is more than observed in S1, and is more like the patterns observed in both of the matched controls.

Table 3.5.1 shows that the percentage that Jason looked at the text increased compared with S1 when reading aloud, 88%. However, the percentage of time Jason looked at the picture distracters was similar for reading aloud. 7%, compared to S1 as shown on Table 3.5.1. Jason rarely looked at the sheep when he was reading aloud, 1%, which approximately replicates the findings for S1. Of note is the large reduction in time Jason spent looking at the "other" areas of the presented stimuli when reading aloud, 4.%. Table 3.5.1 also shows that the mean



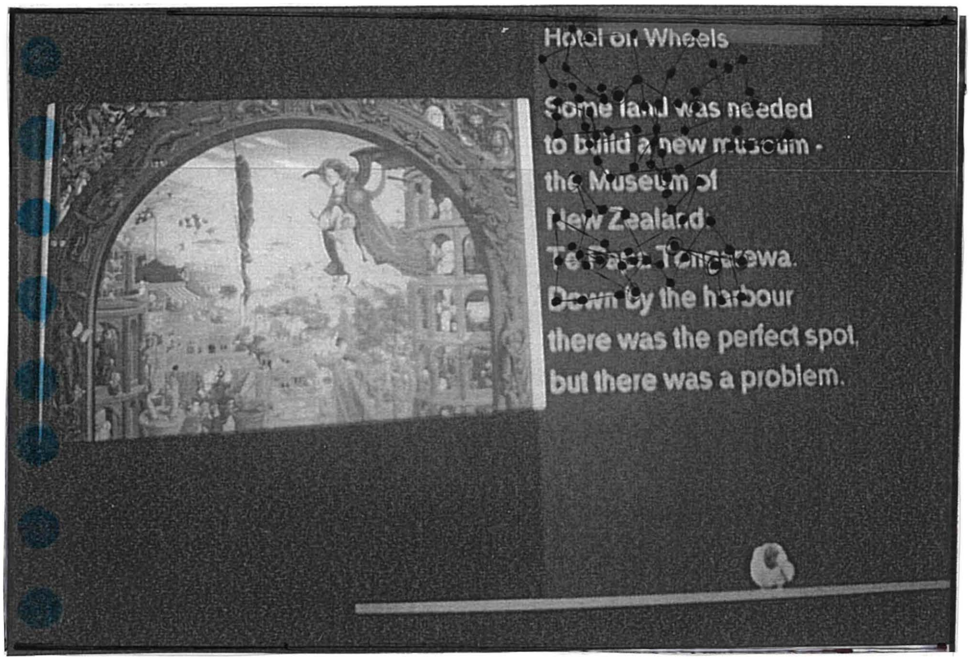
Hotel on Wheels

Some land was needed
to build a new museum -
the Museum of
New Zealand:
Te Papa Tongarewa.
Down by the harbour
there was the perfect spot,
but there was a problem.

KEY:

•	0< 250 ms
⊙	250< 500 ms
△	500< 750 ms
⊡	750< 1000 ms

Figure 3.5.17. Eye movements for Jason when reading aloud, S2.



Hotel on Wheels

Some land was needed
to build a new museum -
the Museum of
New Zealand:
Te Papa Tongarewa.
Down by the harbour
there was the perfect spot,
but there was a problem.

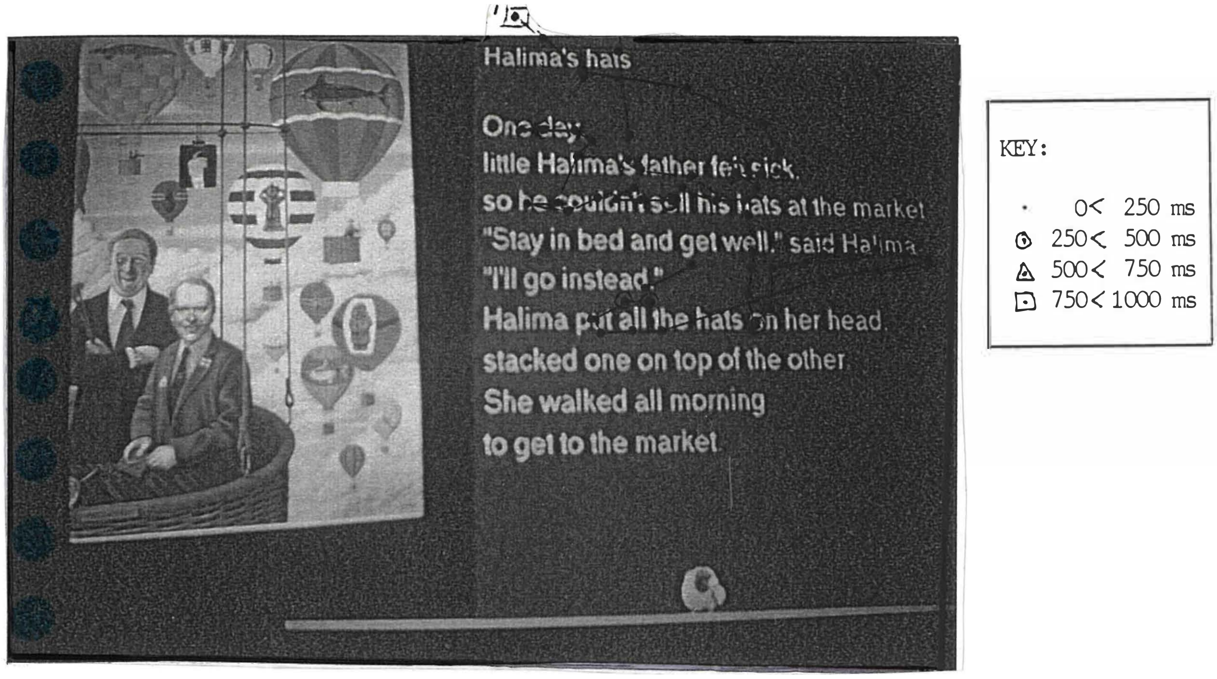
Figure 3.5.18. Eye movements for Mike when reading aloud, S2.

number of words Jason read aloud per minute was, 81.88, and he answered the comprehension questions with slightly less accuracy, 63%, compared to S1.

Figure 3.5.19 shows that the frequency with which Jason missed fixating on each word slightly increased when he was reading silently, a trend also observed in his matched control (see section 3.5.5). Figure 3.5.19 illustrates a mixture of left to right and right to left sequential scanning patterns, using angles of saccades similar in size to those observed when reading silently in S1. One of the differences between S1 and S2 was that there was a noticeable reduction in the amount of re-scanning of words. Figure 3.3.19 highlights that he focused on the text seven times for an interval of between 250-500 ms, the same as observed for S1, and once each on the text and once above the text for an interval between 750-1000 ms.

Table 3.5.1 shows that the percentage that Jason looked at the text increased, compared with S1, when reading silently, 79%. Although the percentage of time Jason looked at the picture distracters was similar to S1, 11%, his accuracy of identifying those that were and were not presented during S2 improved slightly to 100%. Table 3.5.1 also shows that Jason did not look at the sheep when reading silently, which approximately replicates the findings for S1. Of note is the large reduction in time Jason spent looking at the "other" areas of the presented stimuli compared to S1 silent reading to 10%. Table 3.5.1 also shows that the mean number of words Jason read per minute for S2 when silent reading was, 90.31 which was noticeably faster. Table 3.5.1 shows that even though Jason did not look at all of the words in each story when reading silently he was still able to answer correctly 88% of the comprehension questions.

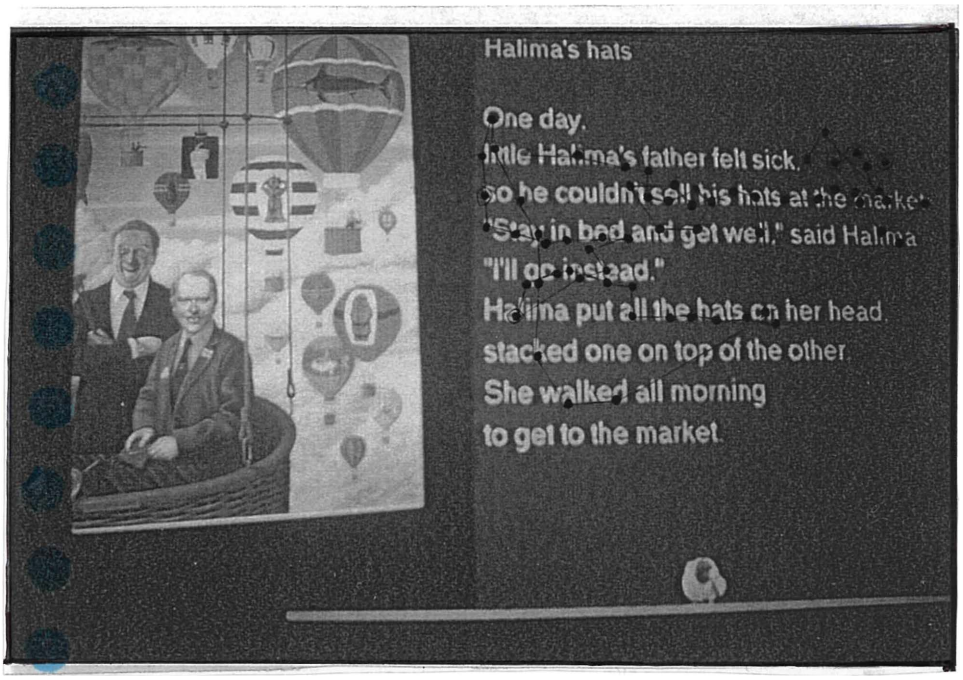
Jason moved his legs a similar amount compared to S1. Figure 3.5.22 shows that Jason's mean number of leg movements per minute when reading aloud was 13, and was 2 when reading silently. He did not move the steering wheel at all during S2. Jason took 2 min 21 s to read the first story aloud, and 2 min 47 s, to read the first story silently, which was slightly faster than observed for S1



Halima's hats

One day,
little Halima's father felt sick,
so he couldn't sell his hats at the market.
"Stay in bed and get well," said Halima.
"I'll go instead."
Halima put all the hats on her head,
stacked one on top of the other.
She walked all morning
to get to the market.

Figure 3.5.19. Eye movements for Jason when silent reading, S2.



Halima's hats

One day,
little Halima's father felt sick,
so he couldn't sell his hats at the market.
"Stay in bed and get well," said Halima.
"I'll go instead."
Halima put all the hats on her head,
stacked one on top of the other.
She walked all morning
to get to the market.

Figure 3.5.20. Eye movements for Mike when silent reading, S2.

3.5.5 MIKE

Mike was the matched control for Jason. Mike's mother and sister accompanied him for both S1 and S2.

Session 1: Mike read the first story silently and began reading immediately, as he did for all of the stories in S1. Mike's eye movements when reading generally followed a repetitive pattern that largely focused on the text. However, he did initially scan the picture distracter at the beginning of the 10 second interval depicted in Figure 3.5.14, using noticeably larger angles of saccades than when reading. His manner of scanning the picture was more controlled compared to the erratic patterns observed with Max (see Figure 3.5.2) or Andrew (see Figure 3.5.5) when scanning the picture distracters. Figure 3.5.14 provides evidence that, like Jason, Mike also scans words forwards and backwards. For example, for the first three words of the second line, Mike focused on each word sequentially from left to right and then again from right to left. Although, when reading the third line he focused on each word sequentially only from left to right. Mike was much more focused on reading the second and third line and the corresponding angle of saccades were noticeabley smaller than in the first line displayed in Figure 3.5.14. Occasionally he would look at the area above the text before he continued to fixate on the words sequentially. Figure 3.5.14 shows that the longest fixation periods were on words, with 14 fixations lasting between 250-500 ms.

Table 3.5.1 shows that the mean percentage of time Mike looked at the text when reading silently was, 92%, similar to when reading aloud, as was the percentage of time spent looking at the picture and sheep distracters, 3% and 2% respectively. However, Mike looked at the "other" areas of the presented stimuli noticeably less when reading silently, 4%. Table 3.5.1 also shows that the mean number of words read per minute for the stories read silently was slightly faster, 90.10, compared with reading aloud. Mike answered the comprehension questions with less accuracy when silent reading, 50%.

Figure 3.5.16 shows that when reading aloud, Mike's scanning patterns again generally followed a repetitive sequence and were slightly more focused on the text than when reading silently. For example, Figure 3.5.16 shows that he focused on each word in each line with generally two to three fixations and relatively small angles of saccades, compared to Figure 3.5.14. Figure 3.5.16, illustrates that Mike fixated on the text 13 times for an interval lasting between 250-500 ms when reading aloud.

Table 3.5.1 shows that the mean percentage of time Mike looked at the text when reading aloud was, 87%. The mean percentage of time he looked at the picture distracter and the sheep was only, 3% and 1%, respectively. However, Mike looked at the "other" areas of the presented stimuli when reading aloud, 9% of the time. He identified the picture distracters with an accuracy of 50%, and identified the pictures not presented with 100% accuracy. Table 3.5.1 also shows that the mean number of words Mike read per minute for the stories read aloud was 82.26 and the accuracy with which he answered the comprehension questions was 100%.

Figure 3.5.21 shows that Mike's mean number of leg movements per minute when reading aloud was 19, and when reading silently was less, 9. Mike did not move steering wheel at all during S1, and took 1 min 27 s to read the first story aloud, which was considerably faster than Jason, and 2 min 37 s, when reading silently, which was longer than Jason took to read the same story.

Session 2: Starting times for S2 took longer than S1, 2 s, when reading aloud, and 6 s, when reading silently. In S1 it was observed that Mike looked at the area above the words as he sequentially fixated on them. This behaviour was still evident during S2, although the pattern was not as clear in Figure 3.5.18 as it was in Figure 3.5.16. This was more apparent when the video of the eye movements was examined in detail. This increased eye movement variability did not affect the fluency with which Mike read the text aloud. Figure 3.5.18 shows that in total Mike focused on the text 13 times for an interval between 250-500 ms. He re-scanned the words he had difficutly reading,such as "Papa," and "Tongarewa." Like Jason, Mike used the re-scanning to self-correct his first attempt at reading these words. Ruff and Rothbart (1996) stated that people generally scan an area to get a general impression of what the story was about. This may explain why Mike scanned over the remaining lines, after reading the end of the third line. This explanation is supported by the fact that during this time he used larger angles of saccades than when reading, that were similar in size to those observed when sweeping between the lines.

Table 3.5.1 shows that Mike looked at the text a similar amount during S2 when reading aloud, 93%. There was a slight increase in the percentage of time he looked at the picture distracters, 5%. Table 3.5.1 also shows that Mike rarely looked at the sheep, 1% of the time. There was a noticeable decrease in the time he looked at the "other" areas of the presented stimuli during S2, 1%. The mean number of words read per minute decreased during S2 to 69.85, as did the level of comprehension when reading aloud, 75%.

As observed for Jason, Figure 3.5.20 illustrates that even though Mike did not focus on each word in the text, he was able to comprehend the story adequately. Figure 3.5.20 shows that Mike, like Jason, was able to sequentially focus on one part of a line, look away and sequentially focus on another part of the same line, but still be able to piece this together and comprehend the story. Figure 3.5.20 shows that Mike only fixated on the text twice for an interval between 250-500, which is noticeably less than observed in S1, and three times on the area above the text for the same time interval.

Table 3.5.1 shows that Mike looked at the text slightly less when silent reading, 85%, but looked at the picture distracters slightly more, 9%, compared to S1. Table 3.5.1 also shows that Mike rarely looked at the sheep distracter, approximately 1% as of the time, which is similar to S1. However, there was a slight increase in the percentage of time he looked at the "other" areas of the presented stimuli when silent reading, 5%. Table 3.5.1 shows that the mean number of words read per minute decreased when reading silently during S2, to 78.47, as did the accuracy with which he answered the comprehension questions, 75%.

Figure 3.5.22 illustrates that Mike's mean number of leg movements per minute decreased slightly in S2, to 5 when he was reading aloud, and to 7 when reading silently. As observed in S1, Mike did not move the steering wheel at all during S2. He took 2 min 47 s, to read the first story aloud which was similar to Jason, and, 3 min 6 s, to read the first story silently which was longer than observed for Jason (see section 3.5.4).

Little change was observed in the behavioural variables that could be accounted for by the order with which Mike read the stories in S1 and S2, either aloud or silently.

4. EXPERIMENT 2

The feasibility of developing a reading training procedure based on suggestions from current literature will also be explored in this experiment. In essence two additions will be made to Experiment 1. These will consist of a prompt prior to, and half way through, each story, asking the participant what their task was and if they were doing it. Secondly, each line of the story will be highlighted based on the individuals' reading speed as an attempt to focus their visual attention.

4.1 Method

4.1.1 Apparatus

The apparatus as described in section 2.2 was used.

4.1.2 Participants

Max, Andrew, John, Jason and Mike completed Experiment 2 (see section 3.1 for a detailed profile of these participants).

4.1.2 Procedure

The General Experimental Procedure as outlined in section 2.7 was followed, however the stimuli presented differed in two key ways. Firstly, the participants current reading position was reinforced by sequentially highlighting each line of the text. Secondly, before each text was presented, and again halfway through the text, each participant was required to read and answer verbally the following statements presented on a fluorescent pink screen with the words highlighted by a fluorescent green bar.

1. What is my task? (Answer)
2. Am I doing it? (Yes I am or No I am not)

At the beginning of the session, the researcher encouraged each participant to remember the last time they were in the experimental room and he was informed that he would be doing a similar task, but with some differences. These differences were explained and a trial of answering the initial prompting screen was modelled by the researcher and then completed by the participant.

During the presentation of the reading training procedure, the text remained white against a dark blue background, however from the moment the participant indicated that he was ready to proceed, each line was sequentially highlighted by a yellow bar. The highlighted area was 0.1 m in width and 1.50 m in length. The speed that the yellow bar highlighted each line was manipulated by a research assistant, based on the speed that the participant was reading. This was achieved by following the eye movements on the adjacent TV screen.

The results from Experiment 1 indicated that randomly assigning the participants to either read aloud or silently first, did not have any noticeable effects on the behavioural variables, therefore all of the participants read the first two stories aloud and the second two silently during experiment 2. This ensured that the research assistant could correctly pace the presentation of the story and the highlighted bar when the participant was reading silently, based on the initial trials where they read aloud.

At the end of S2 and on the day prior to Experiment 2, the participants' parent/caregiver were reminded whether their child should or should not take their morning dose of MPH. Their adherence to these requirements was confirmed before Experiment 2 commenced.

The parents/caregivers and participants were debriefed at the end of the session and thanked for their participation. The parent/caregiver were asked if they would like to receive an outline of the research findings.

4.2 Results and Discussion

The use of the reading training procedure resulted in an increased consistency in the eye movement variables, in the words read per minute and in the comprehension variables when reading aloud and silently. This increased consistency was true for the participants with ADHD and for the matched controls. This is an important improvement as there were considerable differences observed in these behaviour variables between reading aloud tasks and silent reading tasks for the participants with ADHD in Experiment 1. Specifically, for the participants with ADHD the reading training procedure resulted in a considerable reduction in the area of the stimuli they scanned and the size of the angles of saccades they used. The participants with ADHD continued to change their line of gaze rapidly but these tended to centre in the area of the text. The reading prompts suggested by Grainger (1997) did not appear to redirect the participant's attention to the reading task, rather it frustrated them and had little social validity. Therefore, the highlighted bar, designed to draw attention to the area of text the participant was currently reading, was most probably responsible for the improvements observed for both the participants with ADHD and their matched controls.

For the duration of Experiment 2 none of the participants were accompanied by family members or caregivers. All participants reported they were happy to attend on their own.

4.2.1 Max

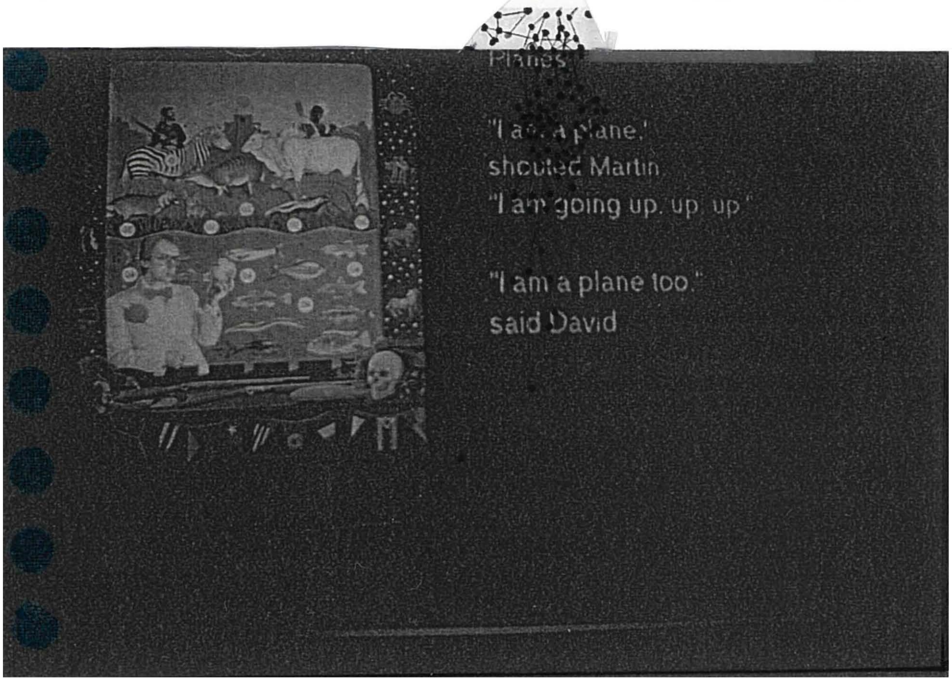
Max completed reading the two stories aloud, but only completed reading one story silently. Subsequently, his initial eye movements were able to be examined, but the data for the other behavioural variables are only based on one story. Max stated that he no longer wanted to continue reading. He had became increasingly agitated at each presentation of the prompt screen and this frustration is the most likely reason why he asked to stop, particularly as this was the only session during which he wanted to stop. Although Max is only one child with ADHD, his reaction may be representative of other children, and thus employing repetitive self-monitoring training may not be the most effective method to increase on-task behaviour for all children with ADHD.

Max took his usual morning dose of methylphenidate (MPH) prior to participating in Experiment 2. As in Experiment 1, Max's eye movements were classified by rapid changes in the lines of gaze and short fixation periods. However, the angles of saccades were noticeably shorter and concentrated considerably more in the area of the text, compared to experiment 1, for both reading aloud and silently.

Figure 4.2.1 illustrates that when reading aloud, Max's angles of saccades were much smaller compared to Figure 3.5.5, and generally concentrated in the middle segments of the title and first two lines. However, the eye movements were so condensed and variable that it was again difficult to determine a pattern to the movement. The larger angles of saccades occurred when Max's line of gaze swept past the last two sentences. He focused on the text four times for an interval between 250-500 ms, which was similar to the results obtained for session 2 (S2) (see section 3.5.1). This supports the hypothesis proposed in Experiment 1 that MPH helped Max focus more on the area required when reading, and the reading training tool did not help increase the fixation durations.

Figure 4.2.4 shows that Max spent the majority of this 10 s interval focusing on the space between the two sets of sentences when reading silently. The angles of saccades were slightly larger than observed when reading aloud, but were comparable to those observed when silent reading in Experiment 1 (see Figures 3.5.5 and 3.5.7). However, as observed when reading aloud there was a dramatic reduction in the area scanned and he was focussing in the area of the text, if not on the text compared to the eye movement behaviours exhibited in Experiment 1. This increase in the time fixated in the area of the text may be due to the fact that the highlighted bar drew Max's attention to the text.

The improvement in scanning and eye movements may account for the noticeable decrease in the mean number of words read per minute during Experiment 2, 9.12 and 13.98 for reading aloud and silently respectively, as presented in Table 4.2.1. Table 4.2.1 also shows that Max focused on the text 89% of the time when reading aloud, which is similar to the percentage observed for S2, and he answered the comprehension questions with the same accuracy, 75%. Therefore, one can tentatively assume that the training procedure did not result in a noticeable difference in the percentage of time that he looked at the text



Planes

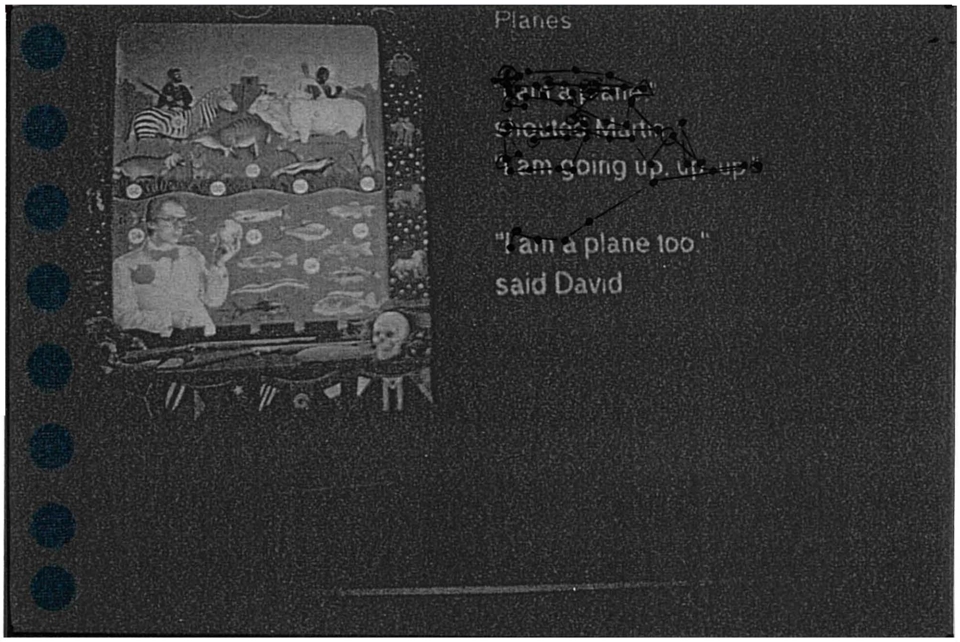
"I am a plane."
shouted Martin.
"I am going up, up, up."

"I am a plane too."
said David.

KEY:

·	0< 250 ms
⊙	250< 500 ms
△	500< 750 ms
□	750< 1000 ms

Figure 4.2.1 Eye movements for Max when reading aloud.

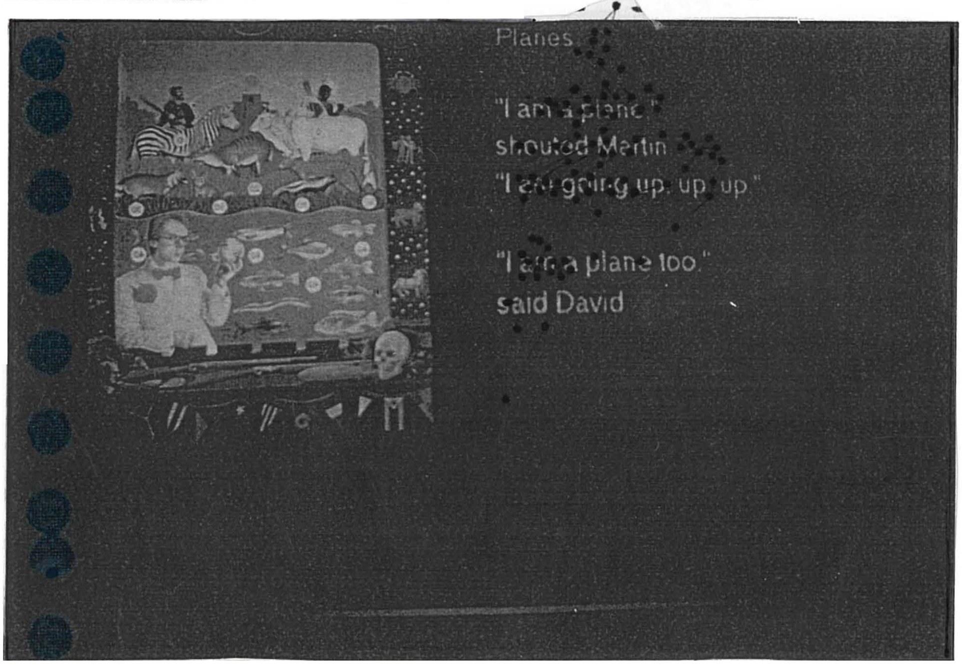


Planes

"I am a plane."
shouted Martin.
"I am going up, up, up."

"I am a plane too."
said David.

Figure 4.2.2. Eye movements for John when reading aloud.



Planes

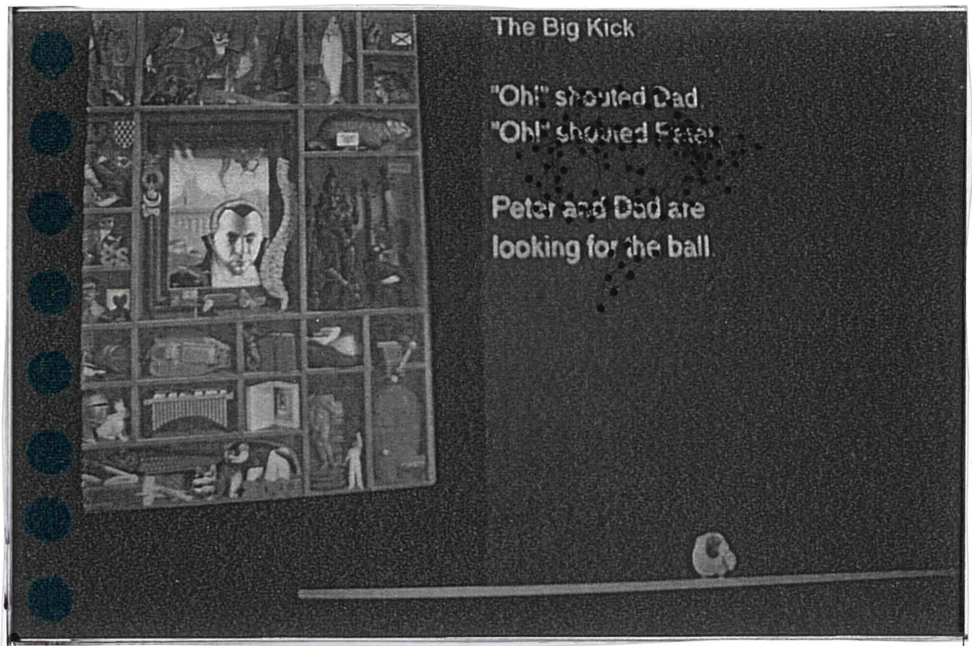
"I am a plane."
shouted Martin.
"I am going up, up, up."

"I am a plane too."
said David.

Figure 4.2.3. Eye movements for Andrew when reading aloud.

KEY:

·	0< 250 ms
⊙	250< 500 ms
△	500< 750 ms
⊡	750< 1000 ms

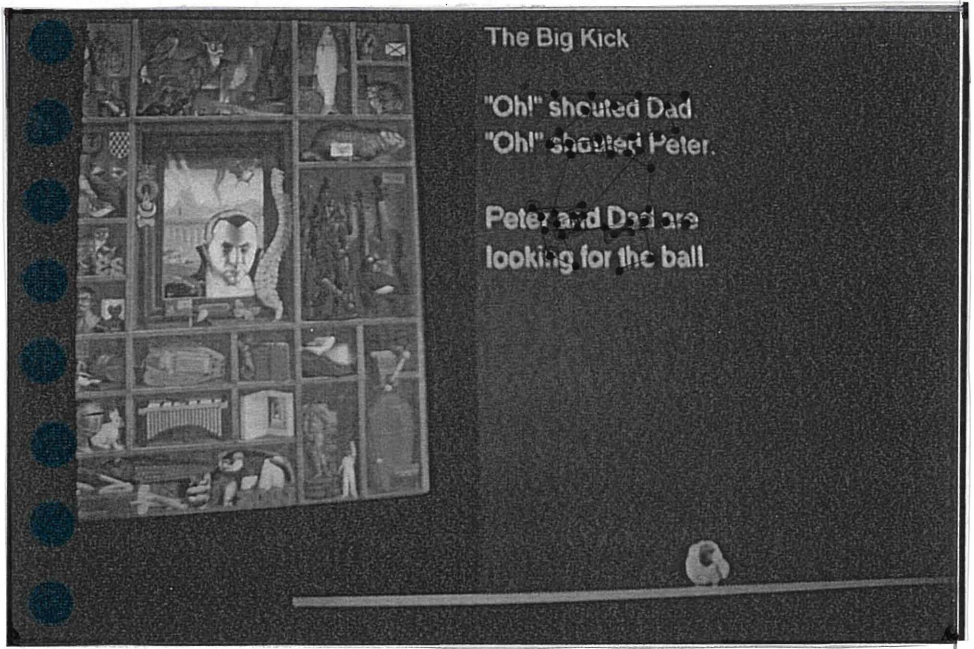


The Big Kick

"Oh!" shouted Dad.
"Oh!" shouted Peter.

Peter and Dad are
looking for the ball.

Figure 4.2.4. Eye movements for Max when silent reading.

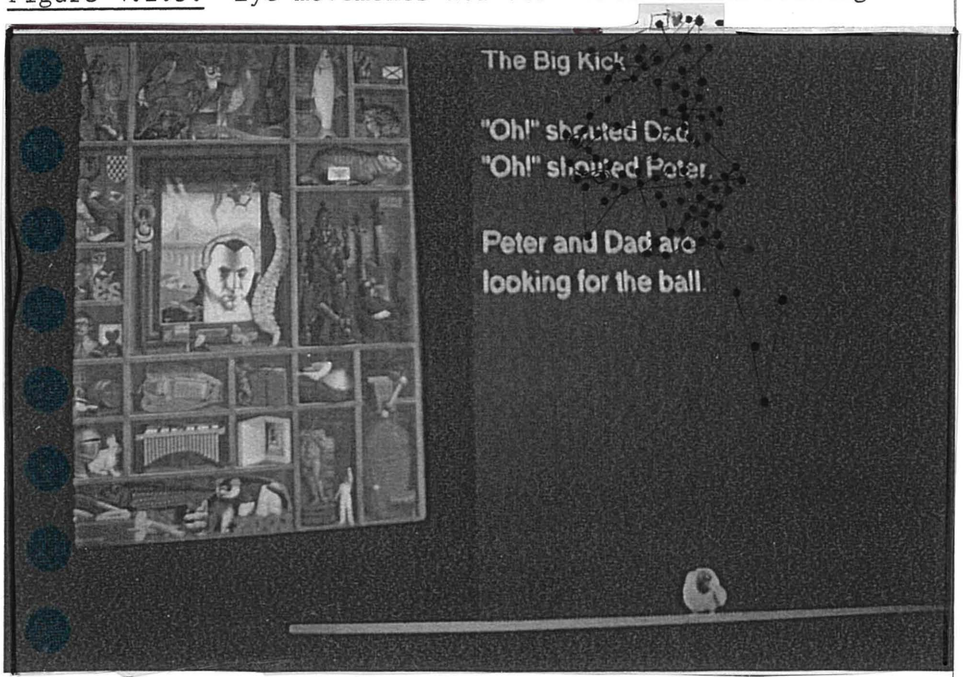


The Big Kick

"Oh!" shouted Dad.
"Oh!" shouted Peter.

Peter and Dad are
looking for the ball.

Figure 4.2.5. Eye movements for John when silent reading.



The Big Kick

"Oh!" shouted Dad.
"Oh!" shouted Peter.

Peter and Dad are
looking for the ball.

Figure 4.2.6. Eye movements for Andrew when silent reading.

Table 4.2.1

Percentage of Time Looking at each Area of the Presented Text, the Mean Number of Words Read Per Minute and the Percentage of Correct answers for the Comprehension Questions and Identification of the Picture Distracters Presented for all the Participants in Experiment 2.

	Percentage of time looking in each area				Words Read Per Minute		Comprehension Questions	Identification of Picture Distracters	
	Text	Picture	Sheep	Other	M	SD	% Correct	% Correct Hits	% Correct Misses
MAX								100	100
Out loud		2.66	0.95	7.67	13.41	6.07	75		
In Head	88.70	14.04	0	3.31	13.98	4.00	25		
	82.64								
JOHN								50	100
Out loud	100	0	0	0	66.34	35.41	100		
In head	100	0	0	0	57.64	16.97	88		
ANDREW								100	100
Out loud		5.93	0.48	47.28	55.69	26.63	75		
In Head	57.85	3.92	0	28.57	51.23	9.19	100		
	67.52								
JASON								100	83
Out loud		4.34	1.89	0	85.61	9.80	63		
In head	92.78	5.39	1.54	0	112.26	22.38	75		
	93.08								
MIKE								100	100
Out loud		1.24	0	2.03	71.83	6.83	75		
In Head	96.73	0.43	0.5	1.71	163.26	26.93	25		
	97.36								

when reading aloud above and beyond the benefits observed after MPH administration alone. Alternatively, there was a noticeable improvement in the percentage Max looked at the text when reading silently, 83%, compared to Experiment 1. Therefore the training tool equalised the percentage of time spent looking at the text when reading aloud or silently. However, he only answered the comprehension questions with an accuracy of 25%, his lowest level observed. Therefore, the training tool appeared to help Max focus on the text more, but did not aid comprehension.

During Experiment 2, Max looked at the distracters less than observed in Experiment 1, 3% for the picture distracter, and 1% for the sheep distracter when reading aloud. Although Max looked at the "other" areas of the stimuli presented slightly more than for S2, 8%, it was still noticeably less than when he did not have his MPH medication. However, when silent reading Max looked at the picture distacter for a similar percentage of time, 14%, compared with Experiment 1, and was able to Max was still able to identify both those were and were not displayed with an accuracy of 100%. However, he looked at the "other" areas and the sheep noticeably less than in Experiment 1, 3% and 0% respectively.

Unfortunately, due to technical difficulties the video camera did not record Max's leg movements for Experiment 2. The cumulative angles of his arm movements when reading aloud were 3104 deg, which was similar to S1, but Max did not move the steering wheel when reading silently. Therefore the considerable decrease observed in his arm movements after having MPH was also observed in Experiment 2, as it was in Experiment 1. Max took a long time to finish reading the first story aloud, 7 min 10 s, and 3 min 20 s, to read the first story silently. This was considerably longer than his matched control, John (see section 4.2.2), and indicates that the training procedure did not help him read faster.

4.2.2 John

The training procedure did not produce noticeable changes in any of the behavioural variables for John compared to Experiment 1, but this was largely because their was limited improvement that could be made. John's eye movement behaviours concentrated on the presented text and he adopted logical and describable reading strategies outlined in previous research (Reichle et al., 1998). For example, Figure 4.2.2 shows that for each line John read aloud, he began by fixating on the first word for a period of between 250-500 ms. Figure 4.2.2 shows that his eye movements over the first two lines can be characterised by scanning either left to right or vice versa and then re-scanning in the reverse order. This pattern was also observed for John during Experiment 1. Figure 4.2.5 illustrates that the re-scanning was not as frequent when reading silently, therefore perhaps, as previously postulated, he felt anxious when reading aloud and attempted to ensure he read aloud correctly. This was the first session in which a care-giver did not accompany John, which may have resulted in an increase in anxiety and subsequently influenced the results. Figure 4.2.2 displays some evidence of his eyes jumping above words in the third line, before he moved on to the next sentence in the third line. This behaviour was also observed for Mike in S2 (see section 3.5.5).

Figure 4.2.5 shows that when was reading silently, he read the first two lines sequentially from left to right, using similar angles of saccades. However, he kept coming back to the word "Peter" in the third line, so it is possible that he found this word difficult and perhaps scanned around the word in an attempt to get a clues for meaning, as taught in the "whole language" approach. Figure 4.2.5 shows that in total John focused on the text seven times for a period between 250-500 ms.

Table 4.2.1 shows that John looked at the text 100% of the time, both when reading aloud and silently, which was a slight improvement compared to Experiment 1. However, he was still able to identify one of the pictures shown accurately, which he may have been able to achieve through peripheral vision, but it is more likely that the obtained 50% accuracy resulted by chance. The mean number of words John read aloud, 66.34, and silently 57.64, as shown in Table 4.2.1, were similar to the rates observed in Experiment 1. Table 4.2.1 also shows that John continued to show a high rate of comprehension, answering the comprehension questions with an accuracy of 100% for the stories read aloud, and 88% when silent reading.

There was no noticeable change in the mean amount of leg movements compared with Experiment 1. Figure 4.2.11show that the mean was 2 for reading aloud, and 7 when reading silently.. As in S2 of Experiment 1, John did not move the steering wheel at all during Experiment 2. John took 1 min 34 s to read the first story aloud, which was similar to Experiment 1, and, 50 s when reading aloud, which was slightly faster than observed in Experiment 1.

After the fifth presentation of the visual prompt John checked with the researcher that he had been answering the prompts correctly and mumbled his displeasure at every subsequent presentation.

4.2.3 Andrew

The results indicate a similar change in the nature of the eye movement behaviours for Andrew as was found with Max (see section 4.2.3). In general, for both reading aloud and silently, Andrew used shorter angles of saccades and eye movements, that still changed fixation points rapidly, but tended to centre in the area of the text, if not on the text, more than observed during Experiment 1. Like Max, Andrew also spent a considerable amount of time fixating on the area between the text both when reading aloud (Figure 4.2.3) and silently (Figure 4.2.6).

Figure 4.2.3 illustrates that Andrew's line of gaze changed very rapidly when he was reading aloud and it is was difficult to identify any dominant pattern in the scanning behaviour. There was a dramatic reduction in the angle of saccades and the area within which the line of gaze changed than observed in Experiment 1. Andrew only focused on the text twice for a interval between 250-500 ms when reading aloud, and as Figure 4.2.3 illustrates, he tended to focus in the area above each line.

Figure 4.2.6 shows that the eye movement behaviours exhibited during silent reading were similar to those observed when reading aloud (Figure 4.2.3). For example, he used smaller angles of saccades to scan a more concentrated area of the text than observed in Experiment 1. Andrew scanned less words when

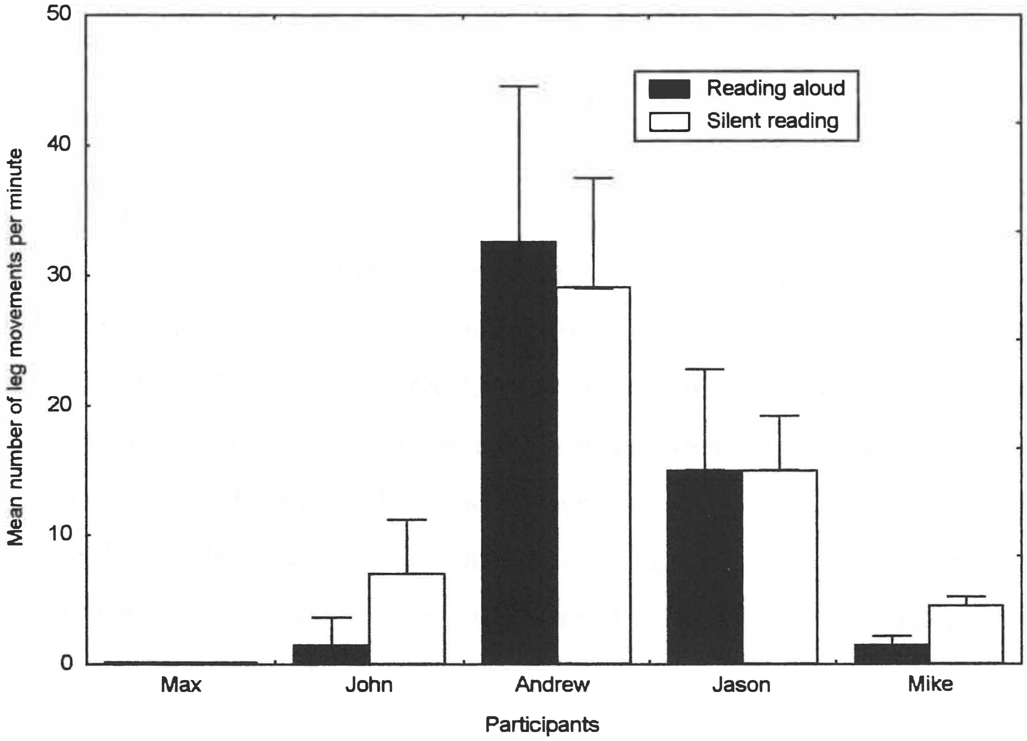


Figure 4 2.11 Mean number of leg movements per minute for each participant when reading aloud and silently, Experiment 2.

reading silently compared to reading aloud, but similar to when reading aloud, he tended to focus in the area above the first and third line. He re-scanned most of the words, but generally not in a sequential pattern. Andrew focused on the text four times for an interval between 250-500 ms when silent reading, similar to that observed in Experiment 1.

Table 4.2.1 shows that when reading aloud, Andrew only looked at the text 58% of the time and looked at the "other" areas of the presented stimuli a similar amount of time, 47%. These percentages are slightly more than observed for S2, therefore it does not appear that the training procedure helped Andrew to focus more on the text. However, there was an improvement in the mean words read per minute, 55.69 when reading aloud, and when reading silently, 51.23, compared to Experiment 1. This is an important improvement given that Andrew's reading rate was fairly consistent throughout Experiment 1 (see Table 3.5.1). Table 4.2.1 shows that when silent reading he focused on the text, 67% of the time, and looked at the "other" areas of the presented stimuli, 29% of the time, both similar to the percentages observed in S2. Andrew answered the comprehension questions after reading aloud with an accuracy of 75% and 100% when reading silently. However, given that he was only looking at the text for slightly over 50% of the time when reading aloud, this level of comprehension is remarkable.

Table 4.2.1 shows that Andrew rarely looked at the sheep, 0.5% and 0% for when reading aloud and silently respectively. The percentage of time he looked at the picture distracter when reading silently was less than in Experiment 1 and was slightly when reading aloud, 4% and 6% respectively. He was able to identify the pictures he did and did not see with 100% accuracy.

The amount that Andrew moved his legs during Experiment 2 was similar to Experiment 1 and again was noticeably more than observed for John (see section 4.2.2). Figure 4.2.11 shows that the mean number of leg movements per minute when reading aloud was 33, and when reading silently was 29. The cumulative angles of arm movements when reading the first story aloud was 49.8 deg, for a duration of 1 min 46 s, which is lower than observed in Experiment 1. When reading the first story silently he moved his arms slightly more, 320.1 deg, for a duration of 58 s. The times taken to read the stories were similar to those observed for John.

Andrew became increasingly frustrated when presented with the visual prompt. When presented with the prompt when silent reading, he answered, “no,” he wasn’t reading, which was the correct response, but the prompt had no effect on returning him to the desired task. Therefore, the reduction in the area Andrew scanned the text and the similarity in eye movement behaviour between reading silently and aloud, not observed in Experiment 1, is most likely due to the bar highlighting his current reading position.

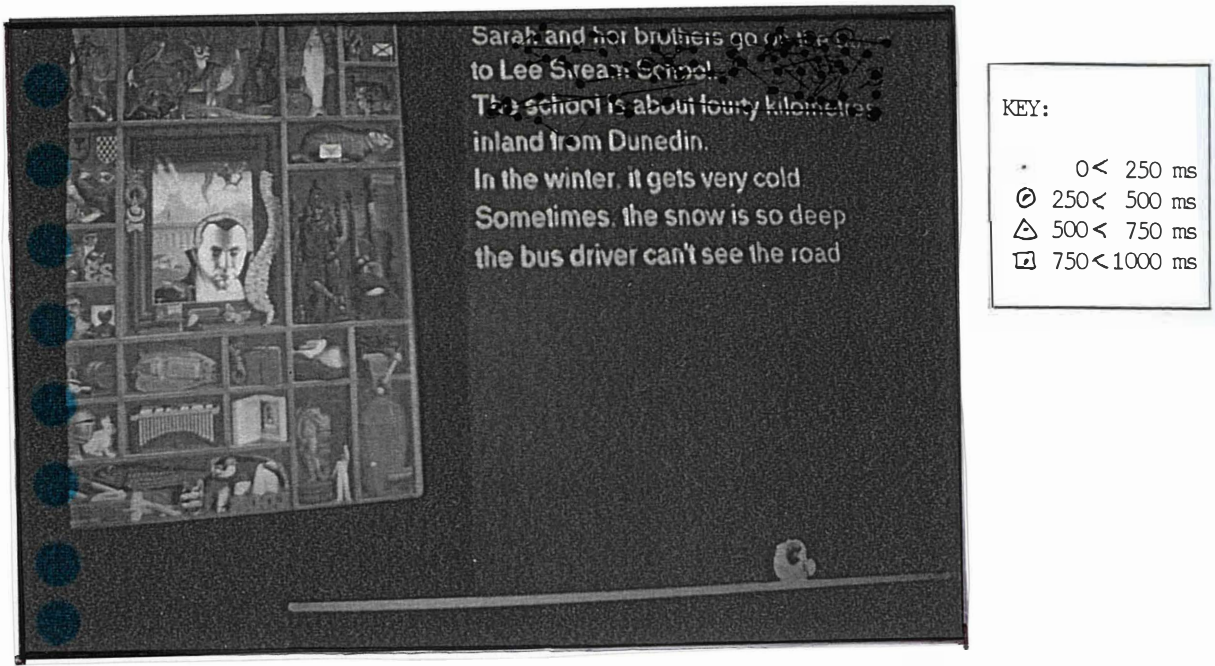
An overview of the results for the three sessions indicate that in general terms Andrew’s performance deteriorated as the sessions progressed. This is not uncommon in children with ADHD in research settings as they become more familiar with the research assistants and the routines (Barkley, 1997).

4.2.4 Jason

Jason’s eye movement behaviours were similar to those exhibited in Experiment 1. The main difference was that there was a noticeable consistency between the eye movement behaviours when reading aloud and silently.

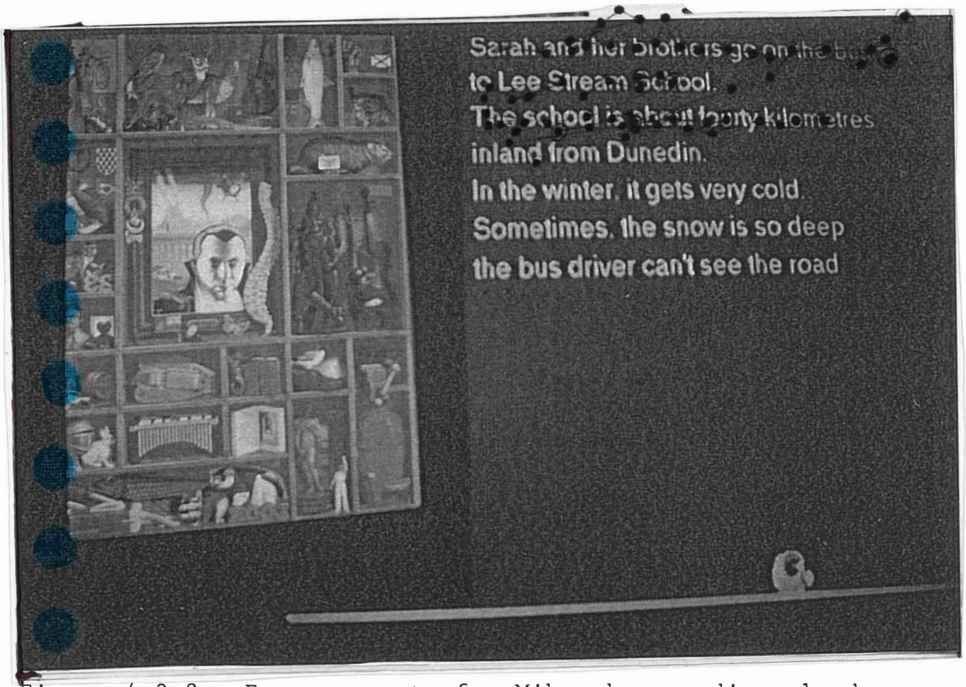
When Jason’s eye movements were analysed in combination with his reading performance, it was observed that even though he did not fixate on every word in the first two lines (Figure 4.2.7), he was still able to read them accurately. Figure 4.2.7 illustrates that when reading aloud, Jason spent a considerable amount of the time looking at the area above the third sentence, after he had difficulty reading the word “kilometer.” Figure 4.2.7 shows that when reading the second line he fixated on each word from right to left then left to right. This pattern of eye movements was also observed in Experiment 1 and therefore may be a dominant reading pattern for Jason.

Figure 4.2.9 illustrates that when he was reading silently, he tended to re-scan words that he had difficulty reading as was described in Experiment 1. For example, Figure 4.2.9 shows that Jason re-scanned the first word of the story using shorter angles of saccades than used in the remainder of the story. During this time, Jason also looked at the picture distracter, using larger angles of saccades, which has been regularly observed when the participants had difficulty with a word. Figure 4.2.9 shows that Jason’s eye movements returned to their characteristic patterns of scanning from left to right and vice versa for the



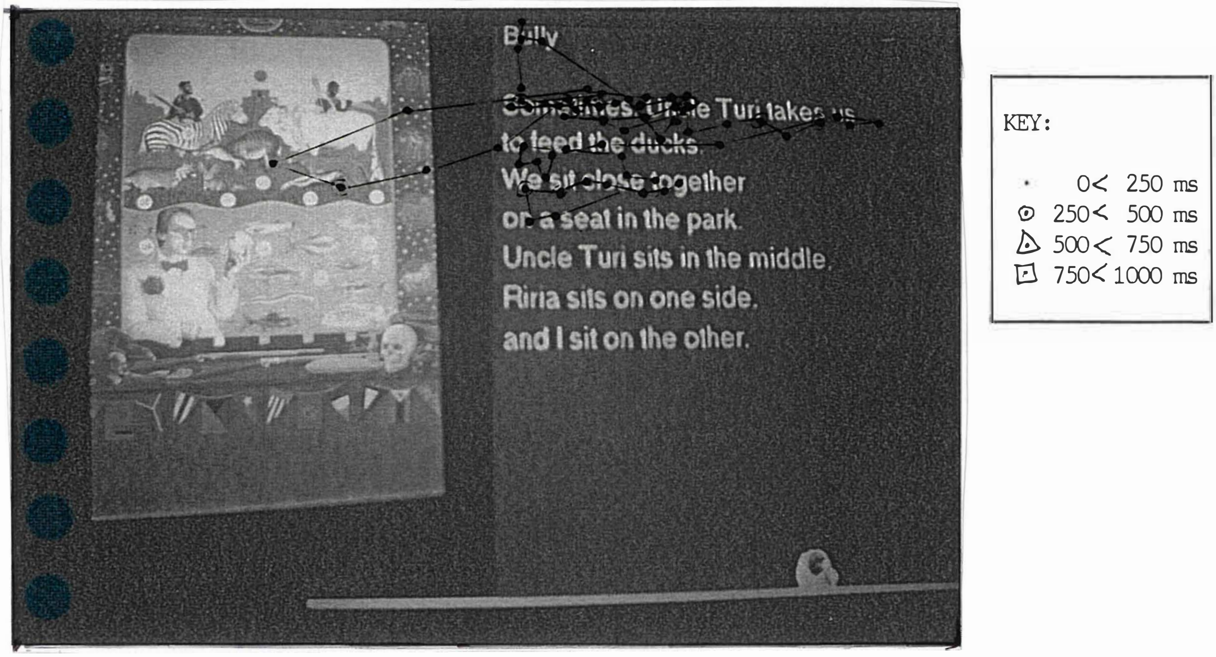
Sarah and her brothers go on the bus
to Lee Stream School.
The school is about fourty kilometres
inland from Dunedin.
In the winter, it gets very cold.
Sometimes, the snow is so deep
the bus driver can't see the road

Figure 4.2.7. Eye movements for Jason when reading aloud.



Sarah and her brothers go on the bus
to Lee Stream School.
The school is about fourty kilometres
inland from Dunedin.
In the winter, it gets very cold.
Sometimes, the snow is so deep
the bus driver can't see the road

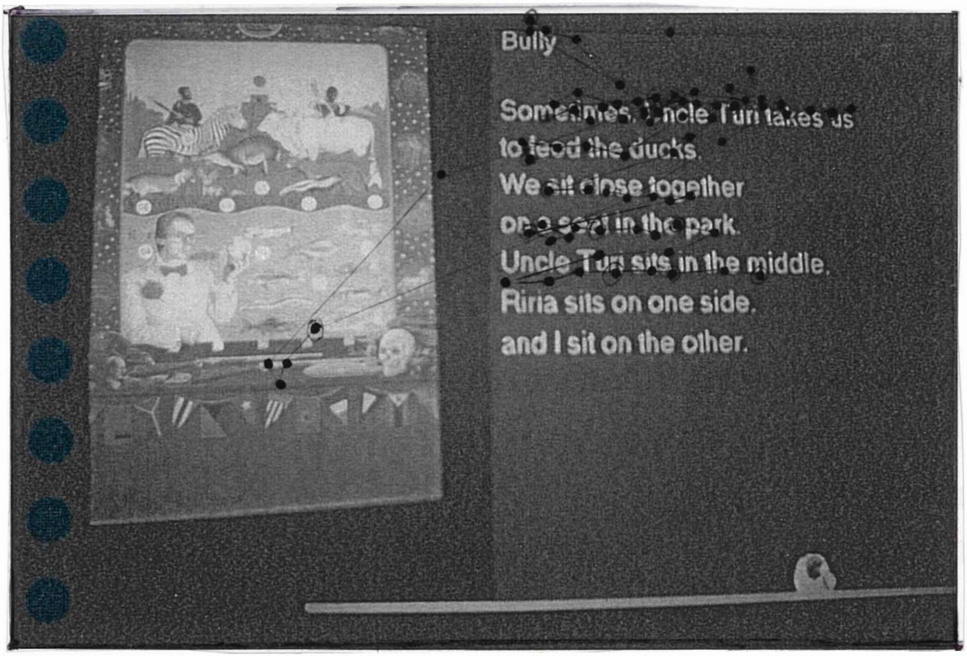
Figure 4.2.8. Eye movements for Mike when reading aloud.



Bully

Sometimes, Uncle Turi takes us
to feed the ducks.
We sit close together
on a seat in the park.
Uncle Turi sits in the middle.
Riria sits on one side,
and I sit on the other.

Figure 4.2.9. Eye movements for Jason when silent reading.



Bully

Sometimes, Uncle Turi takes us
to feed the ducks.
We sit close together
on a seat in the park.
Uncle Turi sits in the middle.
Riria sits on one side.
and I sit on the other.

Figure 4.2.10. Eye movements for Mike when silent reading.

remainder of the 10 s interval. Figures 4.2.7 and 4.2.9 show that Jason fixated eight times on the text for an interval that lasted between 250-500 ms when reading aloud and silently, which is consistent with the behaviour observed in Experiment 1.

There was only a slight increase in the percentage of time Jason looked at the text, 93%, and in the mean number of words read per minute, 53.7, from S2 from Experiment 1 when reading aloud. Table 4.2.1 shows that there was a small increase in the percentage of time spent looking at the text when reading silently, 93%, compared to S2, but there was a noticeable increase in the mean number of words read per minute, 112.26. Jason answered the comprehension questions after reading aloud with an accuracy of 63% and an accuracy of 75% when reading silently, which was similar to Experiment 1.

Table 4.2.1 shows that the percentage of time Jason spent looking at the "other" areas of the presented stimuli when reading aloud decreased over the sessions to 0% during Experiment 2, for both reading tasks. He looked at the picture distracter a similar amount when reading aloud, 4%, compared to Experiment 1 and slightly less, 5%, when reading silently. Jason spent marginally more time looking at the sheep in Experiment 2, both 2% of the time when reading aloud and silently. Jason correctly distinguished between the picture distracters shown and those that were not, with 100% accuracy.

The amount of leg movements varied noticeably during Experiment 1, Jason's leg movements during Experiment 2 were within this previously observed range. Specifically, Figure 4.2.11 shows that his mean number of leg movements per minute when reading aloud was, 16, and was 15 when reading silently . There was a noticeable increase in the amount of arm movements compared to Experiment 1. The cumulative angles of his arm movements for the first story he read aloud was 1011.6 deg, for a trial duration of 4 min 2 s, and was 258.2 deg when reading the first story silently, for a trial duration of 2 min 11 s. In Experiment 1 it was also observed that Jason moved his arms considerably less when reading silently, compared to reading aloud.

4.2.5 Mike

Figure 4.2.8 shows that Mike's attention focused on the text presented when reading aloud. Basically, Mike's eye movements when reading aloud can be described as scanning each word in each line using small angles of saccades, with a number of extended fixation periods. Figure 4.2.8 shows that Mike fixated 13 times on the text for an interval that lasted between 250-500 ms. For the first two lines Mike generally focused on each word sequentially from left to right. When reading the third sentence, Figure 4.2.8 shows that his line of gaze regressed over the first four words. Overall, the pattern of his eye movements when reading aloud did not differ noticeably from Experiment 1.

Figure 4.2.10 illustrates that when Mike was reading silently his eye movements generally fixated on each word sequentially from left to right. However, he used regressive eye movements when reading the first four words of the first line. Figure 4.2.10 also shows that he fixated for a similar number of times on the text, 14, for an interval between 250-500 ms compared to reading aloud.

The similarities observed in the eye movement behaviours between reading aloud and silently for Experiment 2 were also exhibited in the other behavioural variables. Table 4.2.1 shows that the percentage of time that Mike looked at the text was consistent between the stories he read aloud and silently, 97%. These results are more consistent than observed in Experiment 1. Subsequently, Table 4.2.1 shows that the amount of time spent looking at the picture distracters when reading aloud, 1%, and silently, 0.5%, were minimal, as was the percentage of time spent looking at the sheep, 0% and 0.5% respectively. However, he was able to identify the pictures he did and did not see with 100% accuracy, as shown in Table 4.2.1. Table 4.2.1 shows that Mike looked at the "other" areas of the presented text slightly less than in Experiment 1 when reading aloud and silently, 2%. Mike's reading speed was similar to Experiment 1 when reading aloud, 71.83, but was considerably faster when silent reading, 163.26. Jason's reading speed also increased when reading silently, therefore perhaps the training tool increased the silent reading speed of the participants without ADHD. However, it is possible that Mike was not reading the text fully, because he only got 25% of the comprehension questions correct as displayed in Table 4.2.1.

Mike moved his legs less during Experiment 2 than he did during Experiment 1. Figures 4.2.11 illustrates that his mean number of leg movements per minute when reading aloud was 2, and when reading silently was 5. Consistent with the behaviour exhibited in Experiment 1, Mike did not move the steering wheel at all during Experiment 2. He took 4 min 44 s, to read the first story aloud, and 1 min 57 s, to read the first story silently which were similar to the times recorded for Jason (see section 4.2.4).

5. GENERAL DISCUSSION

This research successfully designed a calibration procedure that accommodated the hyperactivity of the participants with ADHD and allowed their eye movement behaviour to be analaysed when reading. The success and social validity of the calibration procedure indicates that it could be used in the future for investigating eye movement behaviour for individuals with similar behavioural difficulties. However, it is important to note that the success of the calibration procedure was facilitated by the main researcher providing each participant with her full attention and the frequent use of positive reinforcement to guide the behaviour, if it appeared that he may adjust or damage the equipment. Even so, eye movement data was lost for Andrew in S1 after he knocked the eye camera whilst moving around in the seat. Nonetheless, the successful development of the calibration procedure is important, given that previously researchers have often found that children with ADHD have difficulty restricting their behaviour in accordance with experimenter instructions in laboratory settings (Barkley, 1997).

The results of Experiment 1 indicate that the participants with ADHD did indeed have discernably different eye movement behaviour when reading, compared to their matched controls. Specifically, their eye movements were characterised by rapidly changing lines of gaze, shorter fixation periods, less evidence of sequential scanning of sentences, prolonged periods of searching the text (prior to commencing reading and whilst reading), the use of larger angles of saccades and tending to take longer to finish reading. The hypothesis that the differences in eye movement behaviour would be related to the symptoms of ADHD, as evidenced by the CTRS-R and the CPRS-R, was supported in all cases. This is an important finding as the CTRS-R and the CPRS-R have well established reliability and validity parameters and are regularly used in research for screening ADHD (Lufi et al., 1997). Therefore, the results of this research indicate that examining differences in eye movement behaviour of children with ADHD could have diagnostic capabilities (Matsushima et al., 1998).

Indeed, similar advances which use eye tracking technology for diagnostic purposes for schizophrenia are currently being explored. For example, Arolt et al. (1998) found that individuals with the residual subtype of schizophrenia could be differentiated from controls with considerable criterion validity based on analysis of smooth pursuit tasks and voluntary saccades. Therefore, the current research findings suggest future research that explores the reliability and validity of this method for distinguishing between individuals with and without ADHD is warranted. The analysis of eye movements may prove to be an effective method for quantifying hyperactivity or attention levels in individuals with ADHD. For example, currently there is increasing evidence that the assessment of motoric activity during continuous performance tasks may be an effective method for quantifying hyperactivity in individuals with ADHD (Teicher et al., 1996). If the findings of this research are replicated and prove to be a valid and reliable diagnostic method, then it may be possible to produce normative data, with screening cut-off points, that indicate the possibility of a diagnosis of ADHD such as those provided by Conners (1997) for the CTRS-R and the CPRS-R.

There are a number of explanations as to why Jason's eye movement behaviour was more like his matched controls, rather than the participants with ADHD. Firstly, he may not have ADHD as indicated by his obtained scores on the CTRS-R and CPRS-R. Secondly, perhaps his extended time in Reading Recovery has helped him develop reading strategies similar to typical child readers at his level. Indeed, Moore and Wade (1998) found that ex-Reading Recovery students were significantly superior on measures of comprehension, reading performance and attitudes towards reading which they suggest indicates that Reading Recovery is effective over the long term. A third possibility is that perhaps either Jason, Max or Andrew, had a reading disability. Indeed, Biscaldi et al. (1998) found a significant correlation between abnormal eye movements and reading disability for participants with dyslexia. Although Biscaldi et al. (1998) investigated different parameters of saccadic eye movements than explored in this study, it remains possible that the differences may be related to the reading disability. There is an increasing body of research that indicates that a number of clinical and neuropsychological differences exist between children with ADHD who also do or do not have a reading disability (Halperin et al., 1997). However this is unlikely as Jason, Max and Andrew have all received Reading Recovery and one would assume if they had a diagnosable reading disability it would have been detected during this time. Nonetheless, a valuable area of future research would be to use eye tracking technology to compare the eye movements of readers with either, and a combination of, reading disabilities and ADHD, to investigate similarities and differences. This would be an important factor when designing reading training procedures because each group may need guidance that focuses on different aspects of reading, rather than a generic Reading-Recovery approach.

Rayner (1998) notes that the fundamental premise of the previous 20 years of research is that changes in eye movements when reading reflect moment-to-moment cognitive processes. Therefore, based on this premise, the differences in eye movement behaviours observed between the participants with and without ADHD when reading may have occurred due to different types of cognitive processing. The fact that differences were observed in eye movement behaviour does not necessarily reflect cognitive deficits, only possible cognitive differences as this research did not find noticeable differences in the comprehension ability between the participants with and without ADHD. This is a remarkable feat given the lack of sequential scanning observed, and it is possible that the participants with ADHD adopted alternative cognitive processes than the matched controls, that are equally effective in facilitating comprehension. This hypothesis is supported by the research of Johnstone and Barry (1996) who found that a group of 10 children with ADHD employed additional cognitive processes when processing task-relevant stimuli compared to matched controls, during an auditory two-tone discrimination paradigm.

If the variation in eye movements do indeed reflect different cognitive processing strategies, then there are a variety of possiblities about the nature of these cognitive strategies. One possible explanation is that the participants with ADHD processed the information during the many saccades made when reading. Previously, it was theorised that cognitive suppression occurred during saccades (Takeda et al., 1998), however recent research is beginning to dispute this idea. For example, Irwin (1998) demonstrated that lexical processing is not suppressed during saccades and suggested that saccade durations should be considered in eye movement studies of reading. Consequently, it may be beneficial for future research to investigate the nature and length of the saccades to explore whether individuals with ADHD do make use of this time for processing information more than controls.

Another possible cognitive strategy may be that the participants with ADHD may be able to remember the words they scan over as their line of gaze changes rapidly and thus comprehend the story. Indeed, Ross et al (1994) did not find any differences in the visual-spatial memory of participants with ADHD and their matched controls during a delayed response task. Therefore, perhaps the participants in this research made use of their intact visio-spatial memory to recall what they had seen and could hence comprehend the story. Irwin and Gordon (1998) found that the accuracy of identification of letters presented near the targets of saccadic eye movements was high and concluded that attention determines what is encoded and remembered across eye movements. These findings also provide support for the hypothesis that children with ADHD may make use of their memory systems to deal with what appears to be a lack of control over their eye movements.

Another explanation may be that the participants with ADHD are skilled in reading and recalling words available in their peripheral vision. Holmes et al. (1977) found that some information is at least partially processed in the peripheral region. Indeed, there was evidence in the current research that all of the participants could read words accurately that were only available in their peripheral vision. However, the participants with ADHD read noticeably more words that were only available in their peripheral vision. It is possible that the peripheral vision of the participants with ADHD was more active than the participants without ADHD and this resulted in them frequently changing their area of visual focus as their peripheral vision may have been more active in detecting information and hence acting as a precursor to eye movement. Takeda et al. (1998) stated that the increased visual input requires more attention and longer durations to sort out, in terms of which visual information to attend to and which to discard. This could also account for the increased amount of time it took the participants with ADHD to finish reading the stories, compared with the controls.

The previous research on children with ADHD largely focuses on their deficits and rarely highlights their abilities. This research found that the participants with ADHD not only could comprehend the stories with comparable accuracy to the matched controls, but were also able to re-focus their attention on to the text without prompting. Max and Andrew frequently redirected their line of gaze, albeit through erratic eye movements, and self-corrected a number of their reading mistakes. The observation that the self-correction was repetitive may indicate that the cortical area affected in ADHD may be related to the control of eye movements, whereas the area responsible for monitoring eye movements may not be largely affected and subsequently redirects the eye movements when a mistake is detected. Schall and Hanes (1998) hold that the frontal cortex is responsible for purposeful eye movements and that the neural processes in the supplementary eye field do not participate in the control of eye movements but seem to monitor performance. Therefore, perhaps the results of this research suggest that for individuals with ADHD the frontal cortex is affected and the supplementary eye field still functions effectively.

The eye movement behaviour observed in the participants with ADHD may indeed reflect biological aspects of the biochemical and arousal/attentional systems. Such an hypothesis is supported by Caplan et al. (1996) who explained the lack of change in the spontaneous blink rate across different cognitive conditions for individuals with ADHD in terms of biological differences. Biological explanations for ADHD are supported by the increasing number of functional anatomical studies that suggest that the covert allocation of attention across a variety of visual tasks is mediated by a set of neural signals in the parietal and frontal cortex (Corbetta & Shulman, 1998). Max and Andrew performed more leg and arm movements on average during Experiment 1 and 2 compared to John. Given that they also performed more eye movements than John, it is possible that there is a connection between these two behavioural variables. It is possible that these hyperactive eye movements are a symptom of ADHD, just as gross motor hyperactivity is (American Psychiatric Association, 1994). If the areas responsible for gross motor movements are affected, resulting in the frequently observed hyperactivity, it may be possible that the areas responsible for eye movement are similarly affected by ADHD. If this is so, a possible explanation may lie in the hypothesised link between the parietal and frontal cortex in ADHD. Corbetta and Shulman (1998) proposed that the cortical areas involved in oculomotor programming and execution are involved in shifts of visual attention. Perhaps there is a global difference in the parietal cortex in ADHD that affects visual attention and gross motor movement given this proposed frontal-parietal network.

Alternatively, the difference in the saccadic control between the participants with ADHD, compared to the matched controls, may possibly be related to an attentional developmental delay. Barkley (1997) highlights that if there is a deficit in executive functioning, it is possible that children with ADHD would perform like younger children without ADHD. Munoz et al. (1998) found that young participants (5-8 years of age) exhibited intra-subject variance in the onset of eye movements and had the most direction errors in an anti-saccade task compared to other age groups. Munoz et al. suggest that such patterns reflect the stage of normal development in the nervous system and attribute this to the delayed maturation of the frontal lobes. Therefore it would be valuabe to examine the eye movement behaviour using eye tracker technology across different age groups for children with and without ADHD to explore the possibility of an attentional developmental delay.

On the other hand, perhaps the rapidly changing eye movements were related to the hypothesised difficulty in response inhibition that is thought to be one of the primary deficits in ADHD (Ross et al., 1994). Therefore, the results of this research could be explained in terms of the participants with ADHD having difficulty inhibiting their eye movements. This hypothesis is supported by the fact that the participants with ADHD also tended to look at the distracters and the `other' areas of the presented screen more than the matched controls. It is possible that Max and Andrew paid more attention to the distracters as they could identify them with greater accuracy than John. The overall level with which the distracters disrupted their attention did not reflect the considerable level of disruption that Pearson et al. (1995) found when they presented invalid cues to a group of children with ADHD. Barkley (1997) holds that the capacity to maintain one's performance toward a task despite distraction may be an indicator of interference control. The fact that all of the participants involved in the current research continued to read even in the presence of the sheep moving through their field of view indicates that they had quite a good level of interference control, with or without ADHD. Even if one holds that looking at the distracters represents off-task behaviour in the current research, it did not interfere with the particpants with ADHDs ability to hold information and answer the comprehension questions with any noticeable difference from the matched controls. This is contrary to previous ideology that holds that poor behavioural inhibition results in an impairment in the ability to store and recall information (Barkley, 1997). Kahneman (1973) states that when objects perceived in the periphery are novel, complex or incongruent, attention is diverted. Therefore, it is possible that improvements observed between session 1 and Experiment 2 in terms of the proportion of time spent looking at the distracters, for all the participants, could be related to the fact that the distracters were no longer novel, and thus when seen in the periphery did not precipitate an eye movement or attentional shift.

One of the main differences observed was that the eye movement behaviours of the participants without ADHD were similar to those outlined in previous research, whereas the eye movements of the participants with ADHD generally did not (Reichle et al., 1998). However, there were a number of similar reading strategies used by both the participants with and without ADHD. Firstly, all of the participants skipped or briefly fixated on words that were frequent, short or predictable which is a commonly observed reading strategy (Reichle et al., 1998). Rayner and Raney (1996) agree that this is a common observation when studying eye movements when reading, however they did not find a frequency effect when the participants searched through texts for a target word. Subsequently they proposed that the decision to move the eyes during reading is made on a different basis than during visual search. If this is correct, the frequent searching eye movements of the participants with ADHD may have resulted from a different decision process when compared to the matched controls. Secondly, in accordance with previous research the length of time that all the participants fixated on a word often increased when they had obvious difficulty reading this word (Daneman & Reingold, 1993). Thirdly, there was evidence that all of the participants used regressive eye movements to look again at difficult words, however this was observed with a higher frequency in the participants with ADHD. Re-focusing on words is often associated with facilitating the many aspects of processing which reading requires (Raney & Rayner, 1993). Recently there has been controversy over the value of including a regression-contingent measure when analysing eye movements while reading (Altmann, 1994). However, on the basis of this preliminary research regressive eye movements would be a valuable consideration in future research into the area of ADHD and eye movement behaviour.

Grainger (1997) proposed that slow progress whilst reading and reading difficulties may result in reduced motivation and unhappiness which can be expressed by an increased level of distractibility and inattentive behaviour. Indeed, it was observed for all participants that they often looked away when they had difficulty with a word. However, although John's reading level was below expected for his age he did not display the same level of eye movement variability observed for Max and Andrew, therefore the observed differences cannot be fully explained as a consequence of reading difficulties.

The differences observed between reading aloud and silently were more pronounced for the participants with ADHD in Experiment 1. When silent reading the participants with ADHD did not attend to the text as much as when reading aloud, and were more likely to say they had finished when they had not. It is possible that this may be due to the fact that when reading silently the participants with ADHD did not have access to potential feedback from the researcher, which may have functioned like contingency management strategies that have proven to be effective in increasing on-task behaviour (DuPaul & Eckert,1997). If one assumes that these findings are generalisable to the classroom situation, they suggest attention to reading during silent reading tasks is more likely to be adversely affected than when reading aloud in children with ADHD. However, this tentative conclusion suggests that behavioural problems may be at the root of the reading problems. Indeed, Andrew and Max did exhibit some problem behaviours, such as Andrew moving the eye camera and Max not completing Experiment 2. But for the majority of the time their behaviour was not problematic. Therefore, the results of this research tentatively indicate that the difficulty with reading that the participants with ADHD had are not solely explainable in terms of their behavioural problems, but may be related to their more erratic eye movements.

There was a dramatic reduction in the amount of arm and leg movements Max exhibited during the sessions after he had taken his usual MPH medication. However, it did not reduce them to a level that was similar to his matched control. This reduction in gross motor movement due to MPH replicates previous research findings (Whitmont & Clark, 1996). MPH appeared to reduce the proportion of time Max looked at the picture distracters and the designated `other' areas of the presented stimuli. Therefore, perhaps MPH helped Max direct his attention to the appropriate area for the task at hand. These findings seem to support those of Solanto et al. (1997), who found that MPH reduced task-irrelevant and disinhibited behaviours, such as restlessness in seat. Solanto et al. concluded that these behaviours occur to promote an optimal state of arousal and enhance cognitive performance, but MPH replaced the need for these self-activating behaviours. However, in Max's case it remains that MPH did not reduce the amount of rapidly changing eye movements when reading. Admittedly, these results only reflect the situation for one child, but it is possible that they are representative of a number of children with ADHD. The implications of this are considerable and may explain in part why Max's reading level is behind the majority of his class peers. If we generalise the reduction of leg and arm movements to the classroom setting, this may result in the child moving around the classroom less and thus having less observable off-task behaviours, leading the teacher to attribute this to an increase in on-task behaviour. This hypothesis is supported by Teicher et al. (1996) who found a significant correlation between the complexity of head movements of children with ADHD and teacher ratings of on-task behaviour. However, the eye movement behaviours are not as readily apparent to teachers and would probably not match teacher behaviour ratings. This has serious implications given that eye movements are assumed to reflect cognitive processing (Reichle et al., 1998) as the teacher may assume the child is on task, but it remains that even with MPH they are not functioning cognitively like the typical children. This hypothesis is supported by the findings of Lufi et al. (1997) who did not find that MPH led to significant improvement in cognitive functioning, but did find significant improvement in the teacher rating of classroom behaviour. Indeed, there is a growing body of evidence that challenges the research that suggests MPH improves cognitive functioning. Therefore, there is a need for future research that separates cognitive functioning and behaviour in ADHD in order to explore any differences MPH may produce. The results of this research highlight the use of employing single-subject design with regards to researching the effects of interventions for ADHD. Gulley and Northup (1997) hold that such designs are important because they reduce the chance of subjective teacher and parent judgements that may be biased, affecting the research outcomes.

The current research found that the administration of MPH did increase the proportion of time Max looked at the text when reading aloud to a similar level compared to his matched control. This supports the findings of Lufi et al. (1997) who found that MPH did improve learning performance. However MPH had a limited effect when silent reading, while on the other hand, the combination of MPH and the training procedure in Experiment 2 resulted in a consistently higher proportion of time looking at the text. Therefore it is possible that this combined approach was beneficial in helping Max sustain attention on reading Indeed, Mathes and Bender (1997) found that a combination of pharmacological interventions and self-monitoring procedures increased participants on-task behaviour. In the future it would be beneficial to undertake research into the effect of MPH alone and in combination with specific guidance for reading using a double-blind placebo controlled study.

The concept behind the training procedure was to design a practical procedure to direct attention to the text, based on the assumption that visual attention would benefit from direct guidance. The use of the reading training procedure was successful in that there was an increased consistency observed in the eye movement variables, in the words read per minute and in the comprehension variables when reading aloud and silently. This increased consistency was true for the participants with ADHD and for the matched controls. This is an important finding as there were considerable differences observed in these behaviour variables between reading aloud tasks and silent reading tasks for the participants with ADHD in Experiment 1. Specifically, for the participants with ADHD, the reading training procedure resulted in a considerable reduction in the area of the stimuli they scanned and the size of the angles of saccades they used. The participants with ADHD continued to change their line of gaze rapidly but these were more centred around the area of the text. Indeed, Mathes and Bender (1997) state that interventions with children with ADHD should be very specific in the direction and identification of the target behaviour if they are to be effective in improving on-task behaviour. A similar method in principle was used by Frea (1997) who was able to decrease stereotypic behaviour in two adolescents with autism by increasing their orienting responses to their environment using external prompts. It would be valuable to investigate the effectiveness of the training procedure over an extended period of time. The eye tracker technology and the calibration procedure outlined in this research could be used to establish a baseline measure of eye movement behaviour and intermittent monitoring of the child's progress with various interventions. The advantage of this training procedure is that it was computer generated and hence could be developed into a computer programme for home and school use if the effectiveness is replicated in future reserach.

Alternatively, the reading prompts suggested by Grainger (1997) did not appear to redirect the participants' attention to the reading task, rather it frustrated them and had little social validity. The frustration at the prompt screen was the most likely explanation as to why Max did not complete Experiment 2, as he did not want to stop during Experiment 1. However, this could also be explained by the common observation that while initially children with ADHD may adopt a new strategy to help self-monitor, they eventually decline in their adherence to the strategy in later trials (Barkley, 1997). Nonetheless, this strategy could be improved to increase the level of social validity as Mathes and Bender (1997) found that self-monitoring procedures can have a high level of social validity. Previously, it has been hypothesised that classroom interventions for children with ADHD should incorporate reminders of what their task is (Grainger, 1997). This implies that the children with ADHD forget what their task is. However the results of Experiment 2 indicate that they knew what their task was and prompting did not improve their performance. For example, when Andrew was presented with the visual prompt he accurately answered that he was meant to be reading and that he knew he was not doing this. This finding supports DuPaul and Eckert (1997) who hold that, although it is intuitively appealing to train children with ADHD to regulate their own behaviour, this is not generally supported by empirical evidence of behavioural effects. In their meta-analysis of the effectiveness of 63 outcome studies examining the effects of school-based interventions for young people with ADHD conducted between 1971 and 1995 they found that cognitive-behavioural interventions were less effective in terms of behaviour change in the classroom than contingency management strategies and academic interventions for both Within-

Subjects and Single-Subject Design studies. Therefore, a possible improvement would be to incorporate contingency management strategies within reading training procedures.

Recent research suggests that individuals with reading difficulties benefit from a classroom environment where a students' progress is frequently assessed and where programmes are developed in response to individual needs (Wilkinson, 1998). If the findings of the current research are generalisable, such strategies would be extremely important when teaching children with ADHD to read given the observed atypicalities of their eye movement behaviour. One example may be to provide feedback to decrease the frequency of changing eye movements or to provide direction for their eye movements as in Experiment 2. On the other hand, given the ability of the participants with ADHD to comprehend the story, it may not be necesary to change their eye movements, but rather provide them with more time for reading tasks to compensate for their rapidly changing eye movements.However, as Ryan and Openshaw (1996) highlight, there is a reluctance in New Zealand to critically examine the dominant "whole language" approach to reading and hence develop alternative strategies for successful reading. Ryan and Openshaw hold that continued failure to adequately differentiate between groups of children with special needs in terms of reading has contributed to an inability to develop appropriate programmes. This is unfortunate because the findings of this current research indicate that at the beginning reader level the children with ADHD were able to comprehend, even though their reading strategies were different. This may indicate that they have the ability to be successful readers, but it may be possible that as the text becomes more complex their pattern of eye movements may restrict their ability to retain all of the words collected from their erratic text searches and impede their progress as readers. Thus research and resources may be necessary to design programmes that specifically address their potentially unique situation. Admittedly this would take resource allocation which, as Ryan and Openshaw (1996) highlight, often overshadows such fundamental issues of early literacy instruction.

The results of this research raise more questions than answers. However one definite conclusion is that previous and future research in the fields of eye movements and visual attention have a lot to offer those addressing the issues of

ADHD. Unfortunately this link is rarely made, but the results of this research indicate that it would be valuable to incorporate the knowledge available in the domain of visual attention to help understand and investigate the different facets of ADHD, a disorder by definition that hinges on attention.

5.1 Limitations and Improvements

A major limitation of this study was the limited sample pool, due to the difficulty in obtaining a clinical sample that strictly matched the selection criteria. However, the small sample size enabled detailed analysis of the behavioural variables that revealed a number of similarities and differences between the participants with and without ADHD. This was supported by Trausettleklosinski and Brendler (1998) who found that analysing clinical parameters in correlation with reading performance provides valuable information relating to learning effects and can aid subsequent rehabilitation.

Another important consideration is that both Max and Andrew have been learning to read whilst taking MPH which may have indirectly impacted on the results of this experiment. Practice effects from S1 to Experiment 2 could account for the some of the differences observed, particularly when one considers the novel experience of participating in such a technology focused research.

The eye movement behaviour had to be analysed by hand as, even though there is data analysis software available, the participants with ADHD characteristically fixated for less than 250 ms and this information would have been lost within the restrictions of the software. Nonetheless, this process was very time consuming and hence restricted the amount of data that could be analysed.

Although not analysed in detail, it was observed that the children with ADHD often moved the whole head whilst reading. The eye tracker used in this research measured eye position relative to the helmet and can thus represent any number of world coordinates. Therefore it would be beneficial in future research of this nature to use a Magnetic Head Tracking Unit that can combine the head and eye movements to provide the eye point of gaze in world coordinates. However, this equipment is not currently available in New Zealand.

This research has implicated differences in reading, but little is known about any differences in other information processing situations, such as mathematics education. This leaves the question open for the investigation of other information processing situations such mathematics education using eye tracker technology.

Grainger (1997) notes that children with ADHD appear to differ marginally from children without ADHD in laboratory or quiet settings, however in situations where there are levels of distraction they seem to have difficulty regulating, selecting or sustaining attention. Therefore it would be interesting to examine the eye movements of children with ADHD when reading aloud and silently in the classroom situation.

The preliminary findings of this research suggest that further investigation using the eye tracker technology with other groups would be beneficial. Firstly, it would be valuable to repeat this research on adults with ADHD, to explore whether expert and poor readers have different eye movement behaviour. If the expert reader's eye movements are similar to matched controls this may indicate that individuals with ADHD can learn to control their hyperactive eye movements and strategies for achieving control could be incorporated within Reading Recovery programmes. Secondly, the use of eye tracker technology could be used to investigate and compare the eye movement patterns of individuals with ADHD and ADD to see if they adopt similar strategies. Thirdly it would be beneficial to explore whether there are gender or cultural differences between children with ADHD in terms of their eye movement behaviours whilst reading. This could not be explored in this study as all of the participants were identified as European by their parent/caregiver. However, this area of research is important because little is known about cross cultural (Reid, 1995) or gender differences in ADHD (Arnold, 1996).

The children with ADHD appeared to have a wider and prolonged period of searching the text prior to commencing reading and whilst reading. Therefore it would be beneficial to explore in more detail the visual search patterns of children with ADHD. A possible method for this would be to use the Weighted Search Area method proposed by Chi and Chi (1997) which they found was an effective measure for describing human visual search patterns that reflected the search area covered by the participant. Chen, Chen, Lin and Tsai (1998) recently developed a useful parameter for the quantitative analysis of saccadic dynamics that they used successfully to highlight the differences between individuals with and without

Parkinson's disease and to distinguish between groups of different ages. Chen et al. referred to this as the damping ratio that considers the response curve of the saccade as the step response of a second-order transfer function so that even though saccades may be of equal velocity they may differ substantially in dynamics. Such a sensitive measure would be valuable in exploring the differences in saccades observed in the current research between participants with and without ADHD. It is important to note that given that this is such a new methodology there is no data on parameters such as reliability and validity.

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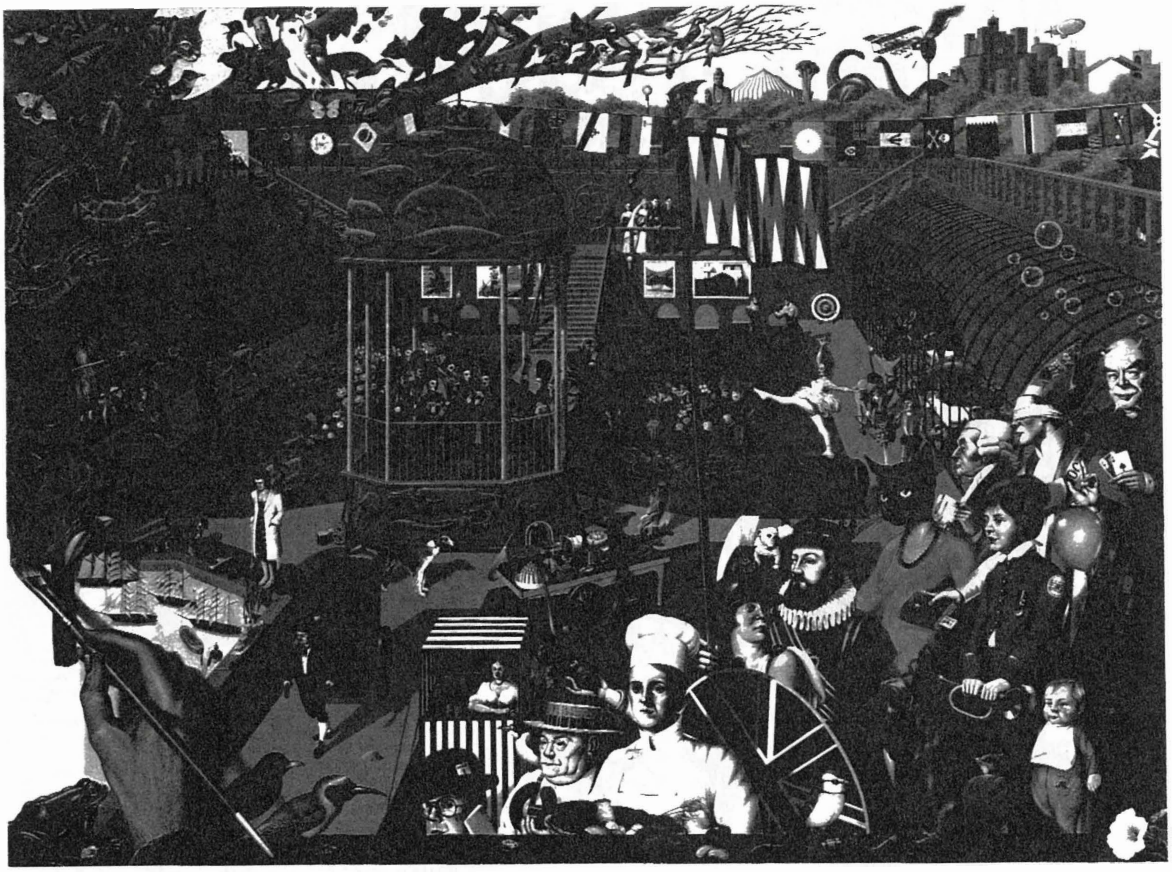
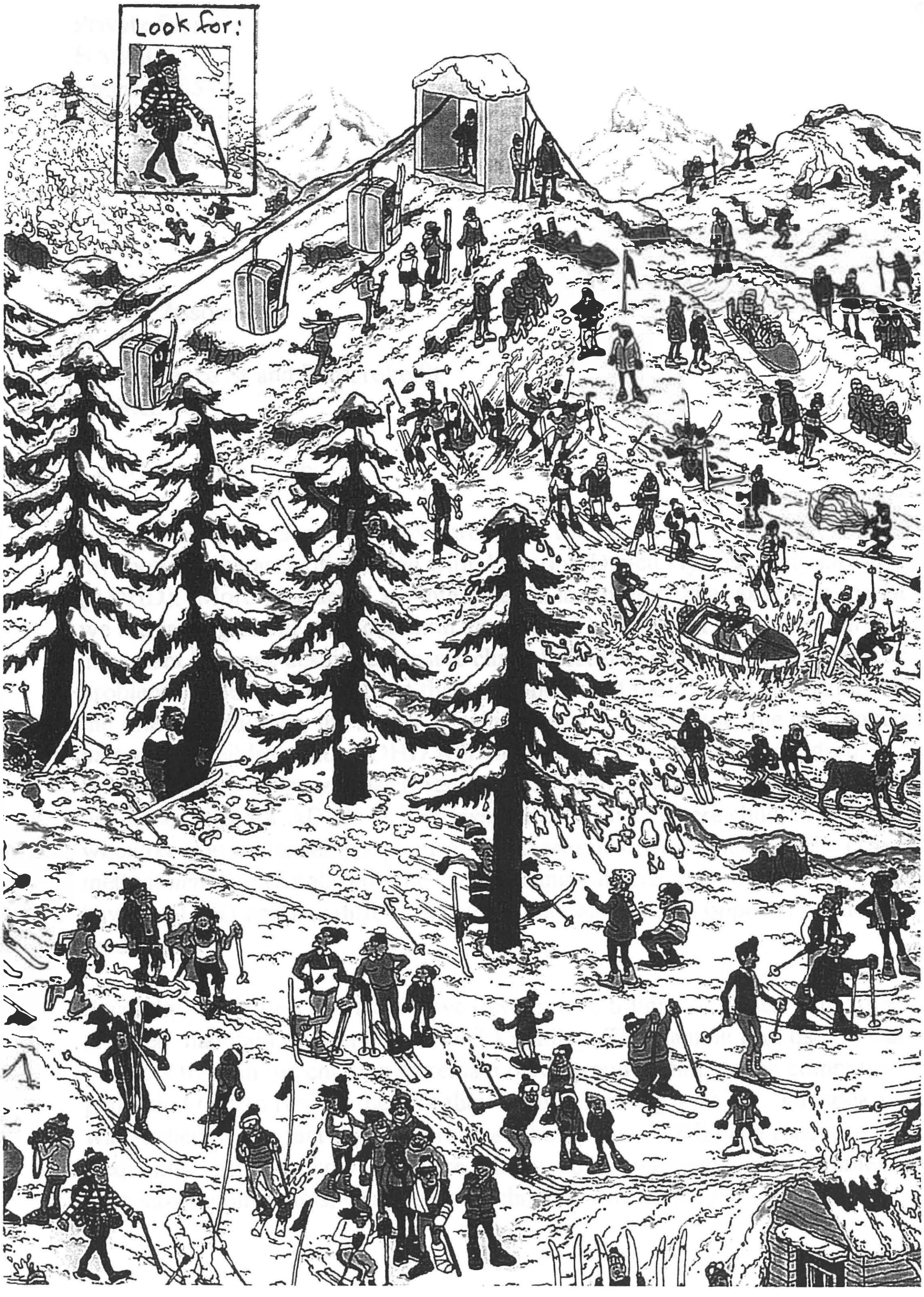
APPENDICES

Appendix 1. Picture distracter



Appendix 2. "Where's Wally?" Puzzle



Appendix 3. Letter to ADHD Association

Kirsty Dempster-Rivett
Psychology Department
University of Waikato
Private Bag 3105
HAMILTON
Phone: 8554122
e mail: kld@waikato.ac.nz

Date

ADHD Association
C / YWCA
Cnr Clarence St and Pembroke St
HAMILTON

To Whom it may Concern,

I am a Masters student currently enrolled at the University of Waikato. I am doing my thesis in the area of children with Attention Deficit Hyperactivity Disorder (ADHD). More precisely I am interested in identifying what exactly is meant when we are talking about their deficit in attention. I believe that such research is important because despite extensive clinical research on children with attentional problems, little is known about the development of basic visual searching skills and the role this may play in ADHD. For my thesis I propose that the eye movement patterns of children with ADHD will differ from those of typical children. Subsequently I propose that current eye tracker technology can be used as a diagnostic tool for ADHD as it allows one to analyse where children are looking when reading or scanning a picture. The research will also examine the effects of methylphenidate (Ritalin) on the eye scanning patterns of children diagnosed as having ADHD and any differences when reading aloud as opposed to silent reading..

Secondly, my supervisor and I have developed a training tool that aims to help children maintain their attention whilst reading. The training tool uses visual prompts to train the children to remain on task and highlights the computer-generated text to remind them of their desired reading position. The idea for this was fuelled by the fact that research has shown that ADHD and reading difficulties frequently co-occur, however there are few computer reading programmes that take into account the special needs of children with ADHD.

Briefly, the research involves the children reading text from school journals that are projected on to a screen whilst their eye movements are monitored by an eye-tracker incorporated in a helmet. The research will be conducted on the university campus on the weekend. This research has been approved by the Ethics Committee for Human Research at the University at Waikato.

To undertake this research I require children with a diagnosis of ADHDto participate who are between 7-9 years of age and currently tainkng methylphenidate (Ritalin). I was wondering if you would give your permission to contact members of the ADHD Association about the possible participation of the children in their care. If you grant your permission I shall be in contact with regards to the most appropriate method of sending the letter to the parents and/or caregivers. I have included the letter that will be sent to the parents. If you have any questions regarding this research do not hesitate to contact me or my thesis supervisor, Dr Robert Isler who is available on phone, 8562889 ext 8401, at the University of Waikato.

If you give your permission for me to contact the parents could you please return the following detachable form in the stamped self-addressed envelope provided.

Yours sincerely,

Kirsty Dempster-Rivett

……

I .... give my permission for the parents/caregivers of children with ADHD to be contacted with regards to participation in Kirsty Dempster-Rivett's research into a new diagnostic and training tool for children with ADHD.

Name:..

Signature:..

Position Held:..

Contact Phone Number:...

Date:..

Appendix 5. Letter to Principal of Knighton Normal School

Kirsty Dempster-Rivett
Psychology Department
University of Waikato
Private Bag 3105
HAMILTON
Phone: 8554122
e mail: kld@waikato.ac.nz

Date

Principal
Knighton Normal School
Knighton Road
HAMILTON

To Whom it may Concern,

I am a Masters student currently enrolled at the University of Waikato. I am doing my thesis in the area of children with Attention Deficit Hyperactivity Disorder (ADHD). More precisely I am interested in identifying what exactly is meant when we are talking about their deficit in attention. I believe that such research is important because despite extensive clinical research on children with attentional problems, little is known about the development of basic visual searching skills and the role this may play in ADHD. For my thesis I propose that the eye movement patterns of children with ADHD will differ from those of typical children. Subsequently I propose that current eye tracker technology can be used as a diagnostic tool for ADHD as it allows one to analyse where children are looking when reading or scanning a picture. The research will also examine the effects of methylphenidate (Ritalin) on the eye scanning patterns of children diagnosed as having ADHD and any differences when reading aloud as opposed to silent reading..

Secondly, my supervisor and I have developed a training tool that aims to help children maintain their attention whilst reading. The training tool uses visual prompts to train the children to remain on task and highlights the computer-generated text to remind them of their desired reading position. The idea for this was fuelled by the fact that research has shown that ADHD and reading difficulties frequently co-occur, however there are few computer reading programmes that take into account the special needs of children with ADHD.

Briefly, the research involves the children reading text from school journals that are projected on to a screen whilst their eye movements are monitored by an eye-tracker incorporated in a helmet. The research will be conducted on the university campus on the weekend. This research has been approved by the Ethics Committee for Human Research at the University at Waikato.

To undertake this research I require children without a diagnosis of ADHD, between 7-9 years of age, with a reading level of 7 years of age to be part of a control group. I was wondering if you would give your permission for me to contact the parents and/or caregivers of a class of children within this age group about the possible participation of their children. I have sent a similar letter to the Board of Trustees asking for permission for this contact. I have included the letter that will be sent to the parents and the relevant teacher for you to view should permission be granted by you and the Board of Trustees. If you have any questions regarding this research do not hesitate to contact me or my thesis supervisor, Dr Robert Isler who is available on phone, 8562889 ext 8401, at the University of Waikato.

If you give your permission for me to contact the parents could you please return the following detachable form in the stamped self-addressed envelope provided.

Yours sincerely,

Kirsty Dempster-Rivett

………………………………………………………………………………………………

I ……………………………………………… give my permission for the members of room to be contacted with regards to Kirsty Dempster-Rivett's research into a new diagnostic and training tool for children with ADHD. The teacher for this room is ………………………

Signature:……………………………………………………………………………

Date:……………………………………………………………………………

Appendix 4 and 6. Letters to prospective participants' parents and/or caregiver. The letter to the parents and/or caregivers of children with ADHD was what was included in the ADHD Associations bi-monthly newsletter.

Kirsty Dempster-Rivett
Psychology Department
University of Waikato
Private Bag 3105
HAMILTON
Phone: 8554122
e mail: kld@waikato.ac.nz

Date

Dear Parent and/or caregiver,

Kia Ora, my name is Kirsty and I am currently a Masters student enrolled at the University of Waikato. The purpose of this letter is to ask whether you would give your permission for your child to particpate in my research. I am doing my thesis in the area of children with Attention Deficit Hyperactivity Disorder (ADHD). More precisely I am interested in identifying what exactly is meant when we are talking about their deficit in attention. I require children without a diagnosis of ADHD to participate so I can compare their results with those from children with ADHD. I believe that such research is important because little is known about the development of basic visual searching skills and the role this may play in ADHD.

For my thesis I propose that the eye movement patterns of children with ADHD will differ from those of typical children. The aim of my research is to design a new diagnostic and training tool for children with ADHD using eye tracker technology. For the diagnostic tool the children will read short school journal stories while ignoring a visual distractor. The training tool uses visual prompts to train the children to remain on task and highlights the computer-generated text to remind them of their desired reading position. The idea for this was fuelled by the fact that research has shown that ADHD and reading difficulties frequently co-occur, however there are few computer reading programmes that take into account the special needs of children with ADHD. The research will also examine the effects of methylphenidate (Ritalin) on the eye scanning patterns of children diagnosed as having ADHD and any differneces when reading aloud as opposed to silent reading.

Briefly, the research will involve monitoring the children's eye movements by an eye-tracker incorporated in a helmet they will wear. The research will be conducted on the university campus on the weekend and will require approximately 3-4 sessions. This research has been approved by the Ethics Committee for Human Research at the University of Waikato and your school principal and Board of Trustees. Please note that if you do want your child to participate, it will not affect your relationship with the school or the University of Waikato in any way. To undertake this research I require children who are between 7-9 years of age and do not have ADHD. If you have any questions regarding this research do not hesitate to contact me or my thesis supervisor, Dr Robert Isler whose phone number is 8562889 ext 8401, at the University of Waikato.

If you are interested return the following form below in the envelope provided. You will be contacted by phone about your future involvement and a time will be made for a meeting to explain the research in more detail and anser any questions you may have. Alternatively you will be contacted by letter thanking you for your interest if your participation is not required. Thank you very much for your time it has been greatly appreciated.

Yours sincerely,

Kirsty Dempster-Rivett

I/we are interested in my/our child participating in Kirsty Dempster-Rivett's research into a new diagnostic and training tool for children with ADHD.

Name:..

Relationship to Child:...

Address: ....
....

Contact Phone Number:...

Date:...

Signature:...

Child's name:...

Child's Date of Birth:...

Best estimate of child's current reading age:.........................

Does your child have any known medical of psychological conditions. Please specify:
....
....
....
....

Does your child have any known visual problems. Please explain
....
....
....

Comments or special considerations:
....
....
....

THANKS FOR YOUR HELP!

Kirsty Dempster-Rivett
Psychology Department
University of Waikato
Private Bag 3105
HAMILTON
Phone: 8554122
e mail: kld@waikato.ac.nz

1 September 1998

Dear Parent,

Kia Ora, my name is Kirsty and I am currently a Masters student enrolled at the University of Waikato. I am doing my thesis in the area of children with Attention Deficit Hyperactivity Disorder (ADHD). The purpose of this letter is to ask whether you would give your permission for the child in your care who has a diagnosis of ADHD to participate in my research. I am specifically interested in children aged between 7-9 years of age. The aim of my research is to design a new diagnostic and training tool for children with ADHD using eye tracker technology. For the diagnostic tool the children will read short school journal stories while ignoring a visual distractor. The training tool uses visual prompts to train the children to remain on task and highlights the computer-generated text to remind them of their desired reading position. The idea for this was fuelled by the fact that research has shown that ADHD and reading difficulties frequently co-occur, however there are few computer reading programs that take into account the special needs of children with ADHD. The research will also examine the effects of methylphenidate (Ritalin) on the eye scanning patterns of children diagnosed as having ADHD and any differences when reading aloud as opposed to silent reading.

Briefly, the research will be conducted on the university campus in the weekend and will require approximately 3-4 sessions. During all of the sessions Alex will not be required to take his Ritalin medication until after the session is completed, if this is what you usually do on the weekend. You and your child are more than welcome to stay and play with a research assistant until the medication takes effect. Previous research has shown that breaks from taking Ritalin causes no harm and may indeed be beneficial for the child. However in the best interests of your child we seek your permission to contact thier pediatrician with regards to their participation.

This research has been approved by the Ethics Committee for Human Research at the University of Waikato. Please note that if you do not want your child to participate it will not affect in any way your relationship with the University of Waikato. If you have any questions regarding this research do not hesitate to contact me or my thesis supervisor, Dr Robert Isler whose phone number is 8562889 ext 8401, at the University of Waikato.

Could you please complete the attached forms and bring them with you on Saturday at 10.30 am if possible. Could you please also pass on the attached letter and rating scale to Alex's teacher, I usually do this in person, but given that you live out of town it would be easier if you could pass this on. I have included a $10 petrol voucher to help with your transport costs and provided a map. Thank you very much for your time has been greatly appreciated.

Yours faithfully,

Kirsty Dempster-Rivett

I/we are interested in my/our child participating in Kirsty Dempster-Rivett's research into a new diagnostic and training tool for children with ADHD.

Name:..

Relationship to Child:...

Address: ....
....

Contact Phone Number:...

Date:...

Signature:...

Child's name:...

Child's Date of Birth:..

Best estimate of child's current reading age:.........................

Teachers name and school your son attends:
....
....

Approximate date of diagnosis of ADHD:.............................

Name of Pediatrician and their address:
....

Does your child have any known medical of psychological conditions. Please specify:
....
....
....
....

Does your child have any known visual problems. Please explain
....
....
....

Comments or special considerations:
....
....
....

THANKS FOR YOUR HELP!

Appendix7. Consent forms for child and their parent and/or caregiver (pp 127)

Psychology Department

CONSENT FORM

PARTICIPANT'S COPY

Research Project:

____

Name of Researcher: ________________

Name of Supervisor: _______________

I have received a letter about this research project and the researcher has explained the procedure to me. I have had a chance to ask any questions and discuss my child's participation with other people. Any questions have been answered to my satisfaction. I understand that my child's name will not appear on any records that will be seen by anyone else other than myself and Kirsty Dempster-Rivett.

I _______________________ give consent for my child to participate as a subject in Kirsty Dempster-Rivett's thesis research. I understand that I may withdraw my child at any time.

Signature: ______________________

Child's Name: ______________________

Printed Name: ___________________ Date: _________________

University of Waikato

Psychology Department

CONSENT FORM

RESEARCHER'S COPY

Research Project:

____

Name of Researcher: _________________ Name of Supervisor:

____

I have received a letter about this research project and the researcher has explained the procedure to me. I have had a chance to ask any questions and discuss my child's participation with other people. Any questions have been answered to my satisfaction. I understand that my child's name will not appear on any records that will be seen by anyone else other than myself and Kirsty Dempster-Rivett.

I _______________________ give consent for my child to participate as a subject in Kirsty Dempster-Rivett's thesis research. I understand that I may withdraw my child at any time.

Signature: ______________________

Child's Name: ______________________

Printed Name: ___________________ Date: _________________

University of Waikato
Psychology Department

CONSENT FORM

PARTICIPANT'S COPY

Research Project:

____

Name of Researcher: ____________________
Name of Supervisor: ________________

Kirsty has told me about her research and has explained what will happen. I understand that it is not a test and all I have to do is my best. I have asked Kirsty all of the questions I have so far and she has answered them in a way I understand. I have talked about the research with my parents and/or caregiver. I know that I can stop coming along at any time and I can stop the procedure whenever I want. I understand that Kirsty will be the only one who will see my name on any of the information collected.

I agree to take part in Kirsty's thesis research

Signature: __________________________
Printed Name: ______________________
Date: ___________________

University of Waikato
Psychology Department

CONSENT FORM

RESEARCHER'S COPY

Research Project:

____

Name of Researcher: ____________________ Name of Supervisor:
____

Kirsty has told me about her research and has explained what will happen. I understand that it is not a test and all I have to do is my best. I have asked Kirsty all of the questions I have so far and she has answered them in a way I understand. I have talked about the research with my parents and/or caregiver. I know that I can stop coming along at any time and I can stop the procedure whenever I want. I understand that Kirsty will be the only one who will see my name on any of the information collected.
I agree to take part in Kirsty's thesis research

Signature: _________________________ Printed Name: ____________________
Date: ___________________