Working memory matters: A series of case studies evaluating the effect of a working memory intervention in children with early onset Otitis Media

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Abstract

Otitis Media (glue ear) delays reading (Kindig & Richards, 2000) by impacting on phonological processing, and may affect working memory development (Mody *et al*, 1999). Reported links between working memory capacity and school success (Bourke & Adams, 2003; Gathercole, Pickering, Knight & Stegman, 2004), suggest that working memory has a crucial role in learning. Deficits have been linked to anxiety during task performance (Hadwin, Brogan & Stevenson, 2005) and low self-esteem (Alloway, Gathercole, Kirkwood & Elliott, 2009).

Sixteen children aged seven to ten with a history of early onset Otitis Media, together with a comparison group of twelve children were assessed on a range of measures of phonological processing, single word and non-word reading, non-verbal reasoning and working memory, and an attitude to self and school rating scale, before and after working memory training. Semi-structured interviews and classroom observations of learning behaviours were used to elaborate the findings from the quantitative data.

Significant differences were found between the groups before training in verbal and visuo-spatial short term and working memory, and non-word reading. Following training these differences were no longer significant. Performance in reading and phonological tasks was found to improve for both groups following training. Mean scores for responses to the learning attitudes rating scales were not significantly different before or after training, but large individual differences were found for children in both groups. Case studies are presented of individual children in the Otitis Media group.

The results indicate that, as found in previous studies, a history of Otitis Media can result in weaknesses in phonological processes, memory and literacy development, and the original contribution of this study indicates that these may be ameliorated by a working memory intervention. Improvements in working memory did not appear to affect children's overall learning identities but more positive feelings were found after training for several children.

Table of Contents

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Finally, I would like to acknowledge the support of my colleagues and pupils at Bridgeworth School.

Declaration of Words

I hereby declare that, except where explicit attribution is made, the work presented in this thesis in entirely my own.

The word count (exclusive of appendices and bibliography) is 44,351 words. The word count for the appendices is 5957 words.

Signed: ______________________________ Date: ____________________________

List of Abbreviations

Abbreviation	***Full Meaning***
ALSPAC	Avon Longitudinal Study of Parents and Children
AWMA	Automated Working Memory Assessment
CTOPP	Comprehensive Test of Phonological Processing
DRC	Dual-Route Cascaded Model of Word Recognition and Reading Aloud
EVT-2	Expressive Vocabulary Test – Second Edition
LTM	Long Term Memory
NFER	National Foundation for Educational Research
OM+	With Otitis Media
OM-	Without Otitis Media
OME	Otitis Media with Effusion
PA	Phonological Awareness
PDE	Phonemic Decoding Efficiency
PET	Processing Efficiency Theory
PIE	Progress in English
PIM	Progress in Maths
PM	Phonological Memory
RN	Rapid Naming
RSME	Rating Scale for Mental Effort
RSPM	Raven’s Standard Progressive Matrices
RWFVT	Renfrew Word Finding Vocabulary Test
STAIC	State-Trait Anxiety Inventory for Children
STM	Short Term Memory
SWE	Sight Word Reading Efficiency
TOWRE	Test of Word Reading Efficiency
WM	Working Memory
WRIT	Wide Range Intelligence Test

List of Appendices

List of Tables

List of Figures

Chapter 1

Introduction

The efficiency of working memory has been reported to affect children's learning experiences throughout their school years. Those with good working memory have been shown to make better progress towards the Early Learning Goals for Writing at the end of the Early Years Foundation Stage at age five (Bourke & Adams, 2010), while those with below average to average working memory have been shown to be more vulnerable to processing efficiency and effectiveness decrements arising from the effects of anxiety (Hadwin, Brogan & Stevenson, 2005; Owens, Stevenson, Norgate & Hadwin, 2008). Poor working memory has been linked to difficulties with literacy and maths, and with different patterns of deficits associated with a number of learning difficulties such as dyslexia, oral language and writing disabilities and attention deficit disorder (Alloway, Gathercole, Adams, Willis, Eaglen & Lamont, 2005; Alloway, Gathercole, Kirkwood & Elliott, 2009; Berninger & O'Malley May, 2011; Gathercole, Pickering, Knight & Stegmann, 2004; Kofler, Rapport, Bolden, Sarver & Raiker, 2010; Kofler, Rapport, Bolden, Sarver, Raiker & Alderson, 2011).

As well as working memory capacity, other factors implicated in classroom success in literacy from Early Years onwards are auditory and speech skills (Hulslander, Talcott, Witton, DeFries, Pennington, Wadsworth, Willcutt & Olson, 2004; Shapiro, Hurry, Masterson, Wydell & Doctor, 2009; Talcott, Witton, Hebb, Stoodley, Westwood, France, Hanson & Stein, 2002), thus children who can hear clearly, pay attention to words and sounds in words, and who have good speech and language skills are more likely to make better progress in all areas of literacy than children lacking these skills. Furthermore, children suffering from chronic middle ear infections resulting in a build-up of fluid behind the eardrum (Otitis Media with Effusion (OME)) have been reported to be more likely to encounter literacy difficulties than children without a history of OME. Children with early onset OME which continued into Key Stage 1, beyond age six, were found to have greater literacy difficulties than control group peers without a history of OME, or where the episodes of OME were not recurrent during early primary schooling (Shapiro et al*.,* 2009). Other studies have demonstrated that children with a history of OME before three years of age achieved lower scores across a range of language and literacy measures, including reading, than OME-free peers (Kindig & Richards, 2000; Winskel, 2006) Links between OME and verbal working memory, have also been demonstrated, with early onset OME sufferers exhibiting reduced capacity compared to their typically developing peers (Mody, Schwartz, Gravel & Ruben, 1999; Nittrouer & Burton, 2005).

Present Study Focus

This thesis focuses on a group of children with early onset OME in Years 3 to 6 at Bridgeworth School (pseudonym), from September 2011 to July 2012. The children took part in an intervention involving Cogmed working memory training (Klingberg, Forssberg & Westerberg, 2002; Psychcorp, 2011). Some of the OME group children had been behind in aspects of literacy and numeracy in comparison to typically developing peers, and demonstrated some learning behaviours which have been linked in the past to poor working memory, such as poor reading comprehension, forgetting instructions, and difficulty with multi-step maths problems. The extent to which the children's sense of well-being at school and their feelings about themselves as learners might be affected by working memory limitations, and the extent to which working memory impacts on learning processes, are of particular interest to me. This is because in my role as Learning Support Coordinator, I have seen many distressed children and parents over the years, as children struggled with aspects of the school's highly academic curriculum.

While being non-selective in the Nursery class, children are informally assessed prior to admission to Bridgeworth School, a suburban independent preparatory school, and admission of children with special educational needs depends on the availability of a suitable framework of support. Teaching is fast-paced and largely undifferentiated. The difficulties experienced by the OME group children in this study are relative, in comparison to their typically developing, but above average peers at this school. Academic standards are high, with most children gaining places at selective secondary schools and a large proportion gaining one of the top 180 grammar school places in the borough, or achieving an eleven plus standardised score of 130+ in the county. For the sixteen years I have been at the school, few children each year have been unsuccessful in gaining a selective place at secondary transfer. The expectation of success places parents and children under a great deal of pressure, the effects of which can be felt throughout the junior school, illustrated by an extract from a conversation with Melody, a Year 3 comparison group participant:

> "*I'm anxious sometimes, but I feel confident I'm going to make it, my 11+. It's three years away*."

Due to my role in leading learning support, I had begun to notice a pattern of characteristics shared by some of the children who found it hard to keep up with the demanding curriculum at our school. These were: poor phonological awareness, inability to detect and appreciate rhyme, mispronunciations of particular phonemes and phoneme clusters and unstressed syllables, and poor attention and concentration. However, I had not been aware that they might be linked to OME related hearing loss. It was rare for parents to approach me, or any other teacher, with the information that their child had OME, or other hearing related problems, possibly because they were unaware that hearing status might impact on learning. A survey of paediatricians revealed that even though respondents agreed that early onset OME impacted adversely on children's speech, language and hearing, they did not necessarily agree that sufferers should be recommended for audiological testing, or that the associated problems would require specialist help to remedy (Sonnenschein & Cascella, 2004). In my experience at Bridgeworth School, children had been seeing Ear Nose and Throat specialists who had not informed their parents that the intermittent hearing loss associated with OME might potentially affect their prospects in literacy, as Harold's (pseudonym) case study in the next section will show.

Parents may not always be aware of changes in their children's hearing and may think hearing levels are satisfactory when there is actually a mild to moderate hearing loss (Brody, Rosenfeld, Goldsmith & Madell, 1999; Rosenfeld, Goldsmith & Madell, 1998). In my particular school context, on several occasions, after parents had been referred to their General Practitioner (GP) because of concerns at school about a child's hearing, parents reported to me that their GP had stated that their child had no hearing problems. Requests for further investigation into the child's hearing met with resistance from the GP. On one occasion, a referral to audiology was refused because, according to medical records, there were no documented ear infections. When the child's hearing was eventually tested, there was reduced movement in one eardrum and hearing loss in that ear. My experience of attempting to refer children for hearing tests revealed a need for better communication between health and education professionals, as miscommunication resulted in unnecessary delays, during which children's education was disrupted. On other occasions, parents were unaware of their children's hearing problems, even though language had been delayed. At my school, children with OME seemed to be neglected, by health and education professionals alike, not deliberately, but due to a lack of awareness of OME's potential impact on academic progress. As previously mentioned, children's Otitis Media status was not something that parents shared with us at school, or that we expressed an interest in, until my involvement with Harold, who was admitted to our Nursery Class in September 2007, aged three, and became the catalyst for this study.

Harold suffered from severe early onset OME resulting in hospitalisation and details of his case follow the literature review in the next chapter. The review first provides an outline of the features and prevalence of OME, and examines difficulties linked with OME and the relationships between auditory discrimination, phonological processing and working memory. Emotional problems experienced by children with OME will be explored. The research issues and methodology selected to address the research questions are outlined at the end of the literature review chapter. Before the literature review, the theories and conceptual models of speech perception, working memory and reading, which shaped and directed this study, are outlined.

Theoretical Frameworks

For the purposes of this study, I am interested in the ways in which OME-related hearing loss may affect children's speech perception, phonological processing, verbal memory and learning at school. The theoretical models explored in this study are speech perception, single word reading and working memory. Speech perception is indirectly linked with reading via phonological awareness (McBride-Chang, 1996; Snellings, van der Leij, Blok & de Jong, 2010), and theories of speech perception suggest the need for verbal storage of the acoustic signal while it is being processed (Cutting & Pisoni, 1978; Hickok & Poeppel, 2007; Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967).

According to Cutting and Pisoni, speech perception is a process involving several stages, each with limited storage capacity. These stages include neural coding of the incoming acoustic signal, and further coding into phonetic and semantic representations, all linked by “a series of memory stores or buffers whose contents are constantly updated and overwritten by subsequent information.” (Cutting & Pisoni,1978, p. 41). If children are affected by intermittent hearing loss related to OME, their ability to process speech sounds will be affected. Work by Maruthy and Mannarukrishnaiah (2008) suggests than one episode of OME between six and twelve months of age is sufficient to significantly affect processing within the auditory brainstem up to age three, which encompasses the critical period for language development (Kindig & Richards, 2000; Ruben, 1999; Ruben, Wallace & Gravel, 1999; Shapiro, Masterson, Hurry, Wydell & Doctor, 2009; Winskel, 2006).

A simple model of speech perception, taken from Cutting & Pisoni, 1978 and shown in Figure 1, proposes that incoming acoustic information is analysed and passed to a sensory information store, after which it undergoes parallel auditory and phonetic feature analysis within a recognition unit. The recognition unit also contains a buffer, which stores material being processed for integration with later-arriving information, and all stages within the recognition unit are linked with short term and long term memory stores. Finally, the auditory information is passed on for parallel lexical, semantic and syntactic analyses.

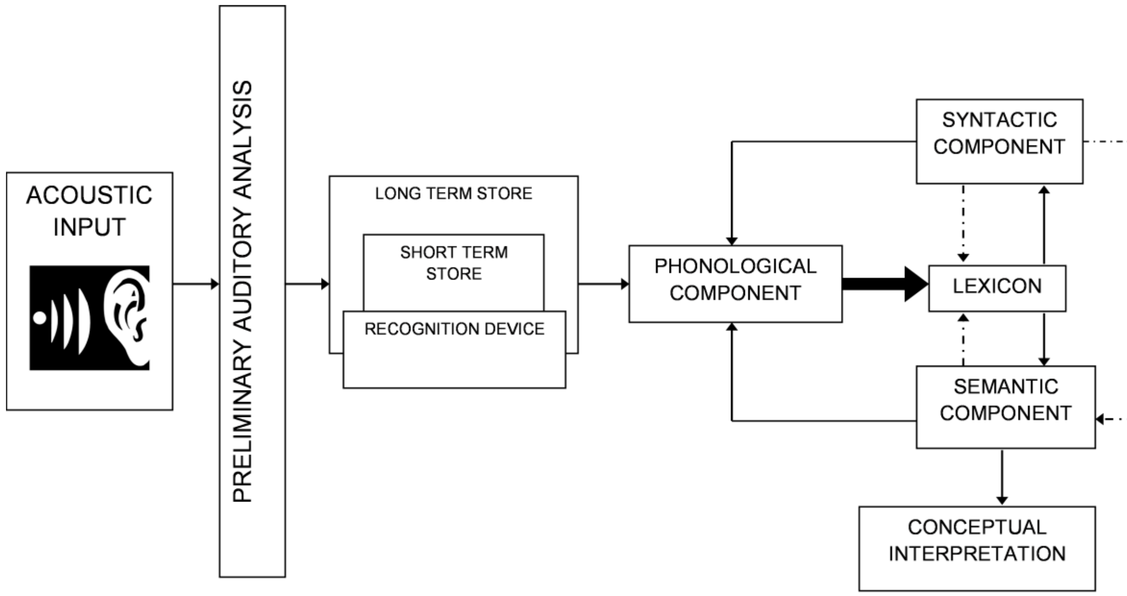

Figure 1. Components of the speech processing system, Cutting and Pisoni, 1978

A study by McBride-Chang (1996) investigated the links between speech perception, phonological awareness and reading in 156 US children, mean age 8;9, by comparing different models of the relationships between speech perception, phonological awareness and word reading. Measures were obtained for IQ, verbal short term memory, naming speed, word reading, phonological awareness and speech perception. Findings suggested that a model which included indirect links between speech processing and reading, mediated by phonological awareness, provided the best fit to the data. Examination of the differences between models suggested that speech perception and phonological awareness are strongly associated, because removal of this link significantly reduced the model fit.

The association between speech perception and reading was further explored in a study by Snellings et al. (2010). Eleven children with reading difficulties and eleven typically developing readers forming a control group, matched for age (mean 7;10), receptive vocabulary and non-verbal reasoning, were assessed on a range of measures. These were: perception of single consonants and consonants within clusters, single word reading speed, receptive vocabulary and non-verbal reasoning. Findings suggested that the children in the control group were significantly faster and more reliable at identifying identical sounds than the reading difficulties group. Possible reasons for this could be that the children with reading difficulties had less well-developed phonemic categories and a more fragile access to phonology than their typically developing peers.

It has been suggested that speech perception is linked with the development of phonemic categories, speed and reliability of phoneme identification and phonological awareness, and phonological awareness is in turn linked with reading development. Reading plays a vital role in academic success, being of primary importance for independent learning in other subjects. Therefore, theoretical models of reading which suggest how early onset OME-related hearing loss might interfere with normal reading development, such as the Dual-Route Cascaded Model (Coltheart, Rastle, Perry, Ziegler & Langdon, 2001; Coltheart, 2006) shown in Figure 2, are relevant to this study.

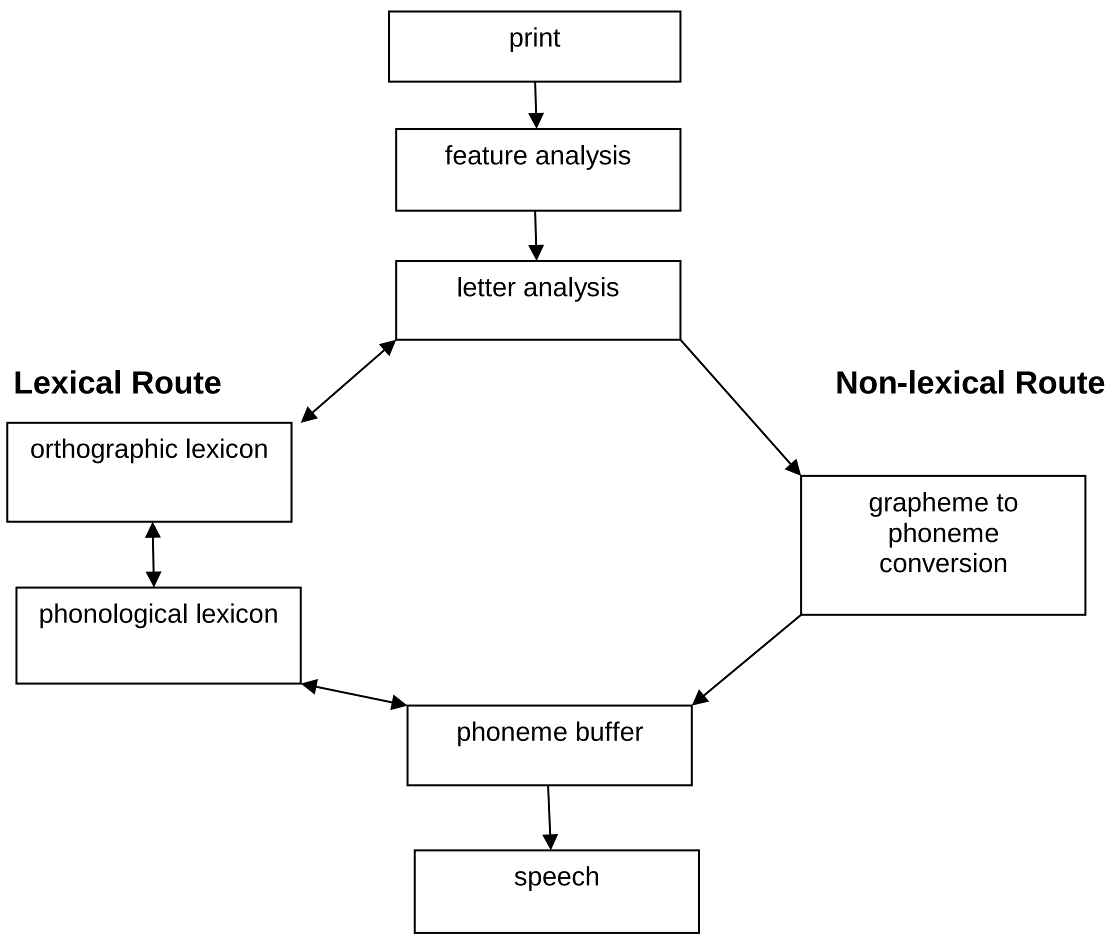

Figure 2. The Dual Route Cascaded Model, of word recognition and reading aloud (from Coltheart 2006)

The Dual-Route Cascaded Model (DRC) suggests that for English, where many words have irregular spellings, two interacting systems, a lexical, or whole word route, and a non-lexical, or phonological decoding route, account for many of the phenomena associated with reading in beginning readers and people with reading difficulties.

The non-lexical route operates by means of grapheme to phoneme conversion rules, but this route on its own would not be able to deal with irregular words, like *once* and *aches,* and processing via this route would result in regularisation errors (such as reading *pint* to rhyme with *mint*). Therefore a lexical route is required to process known whole words, which alone could not deal with non-words or unfamiliar regular words. The DRC model has been shown to be able to accommodate a range of phenomena in the research into reading and has increasingly been employed as a framework for intervention studies with children with literacy difficulties in recent years (see, for example, Kohnen & Nickels, 2008; McArthur & Castles, 2011).

The DRC model is adopted as the framework for thinking about single word reading and decoding in the present study. For text reading both single word recognition and language comprehension processes are necessary, according to the Simple View of Reading (Gough & Tumner, 1986). Verbal and visual memory processes are also involved. Thus, problems with reading can stem from any or all of these (Hynds, 2007; Kirkby & Savage; Loosli, Buschkuehl, Perrig & Jaeggi, 2012; Rose, 2006; Stuart, Stainthorp & Snowling, 2008; Wyse & Styles, 2007).

The relationships between speech processing and single word reading can be illustrated in a general model of language processing proposed by Patterson and Shewell (1987). In this model, shown in Figure 3, the route from print to speech can be traced from top right to bottom left, via the orthographic input and grapheme/phoneme conversion units for non-words, and the orthographic input lexicon, cognitive system and phonological output lexicon for words. Processes involved in word and non-word repetition can also be described by this model, via acoustic analysis and acoustic/phonological conversion for non-words, or via the auditory input lexicon and cognitive system for words.

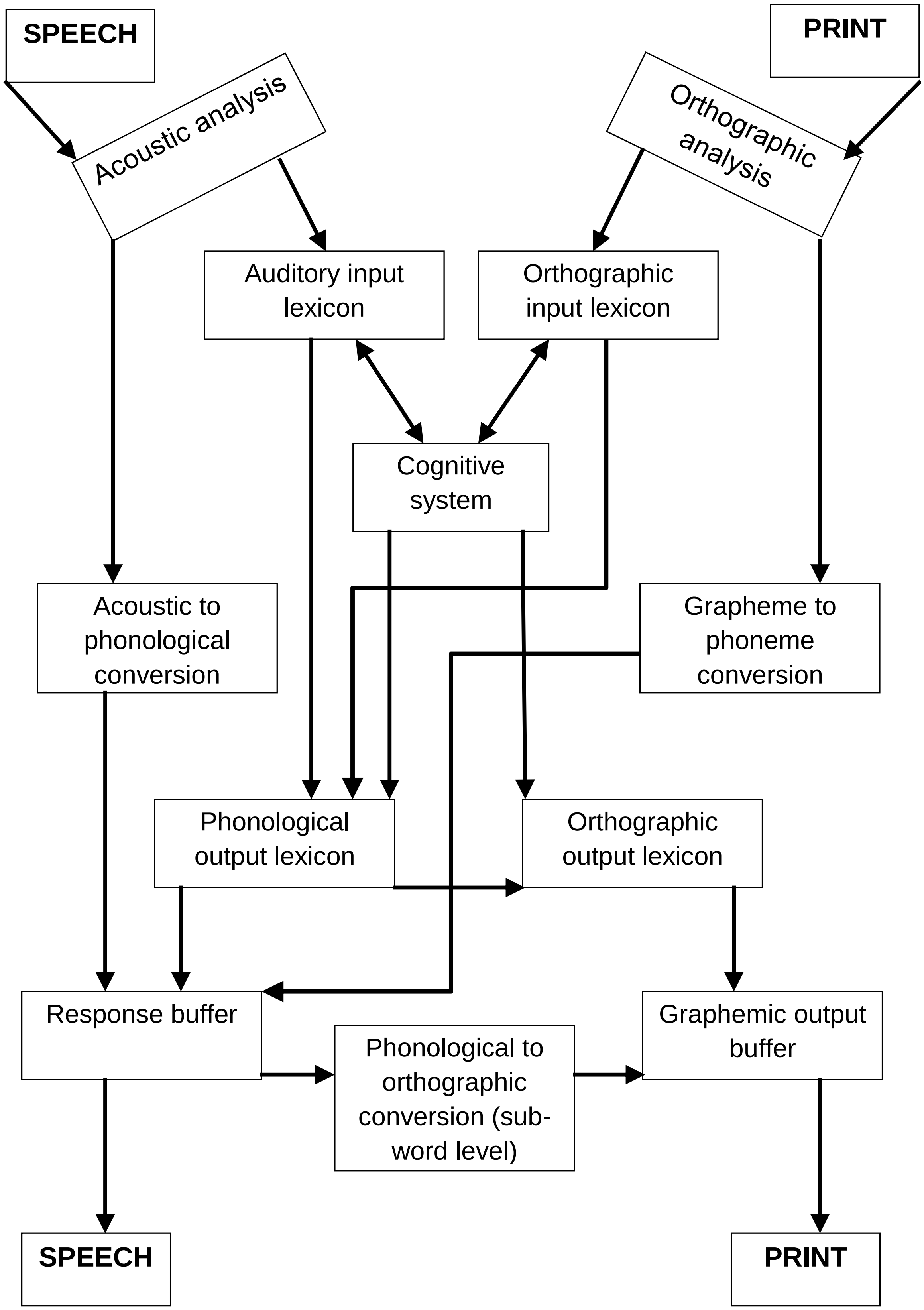

Figure 3. Model of written and spoken language processing, from Patterson and Shewell, 1987

According to Walley, Metsala and Garlock (2003), children's ability to discriminate phonemes develops during childhood, starting with phonological representations of whole words, and gradually becoming increasingly segmented, or restructured, as vocabulary growth demands that more fine-grained phonological representations are created to discriminate between words with many phonological neighbours. This lexical restructuring model of emerging phonemic awareness has been supported by Masterson, Laxon, Carnegie, Wright and Horslen (2005). Masterson et al. (2005) demonstrated that nonwords which are similar to real words are more easily recalled than 'unwordlike' nonwords, possibly because children are able to use their knowledge of real words to create phonological frames to assist in recalling nonwords. Children's ability to recall nonwords improved as their phonological representations became increasingly fine-grained. It is possible that interference to auditory input, as in cases of OME, might affect children's ability to discriminate between phonemes and to develop fine-grained phonological representations, leading to problems with auditory-verbal short term memory when compared with typically developing peers.

In the current study, working memory refers to the limited capacity system conceptualised by Baddeley (1998; 2000), who developed the theory of a modular structure comprising separate verbal and visuo-spatial storage and central executive components. The central executive directs conscious attention and planning, and can be used for processing and storage. A model of working memory, shown in Figure 4, illustrates how the central executive oversees the phonological loop, which stores speech-based input, hereafter referred to as verbal short term memory, and the visuo-spatial sketchpad, which stores visual information, hereafter referred to as visuo-spatial short term memory. Verbal short term memory processes comprise initial acoustic storage, phonological representations resulting from perceptual analysis of the acoustic signal, and the signal sequence (Gathercole, 1999). Information stored in verbal short term memory can be preserved for retrieval by rehearsal. The episodic buffer has a role in retrieving information from long term memory (LTM) and integrating it with contents of working memory.

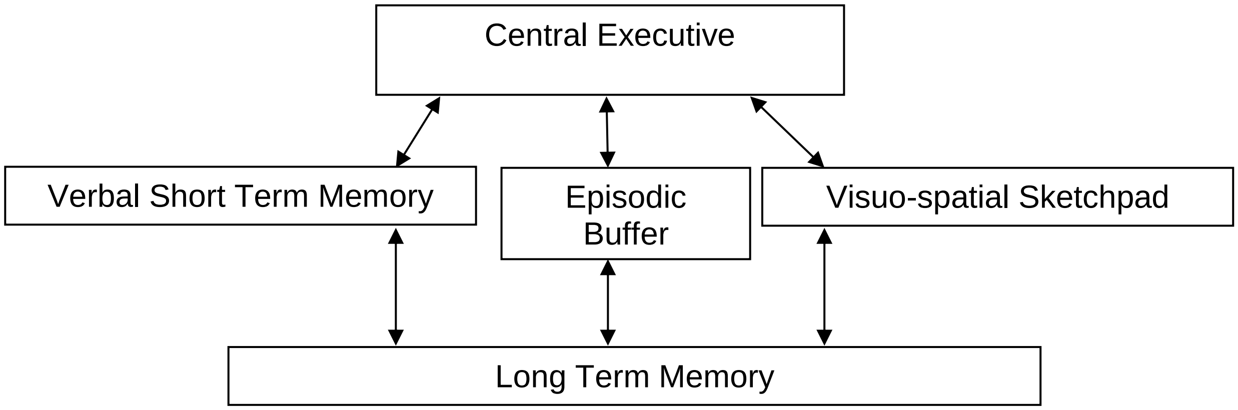

Figure 4. Model of Working Memory, (after Baddeley, 2000)

This section has outlined theories and conceptual models proposing links between phonological processing, verbal memory and reading. The following literature review will examine these links in greater detail.

Chapter 2: Literature Review

Introduction

As previously mentioned, this study is concerned with reading development insofar as reading attainment facilitates school success. Lack of success may lead to a less positive learning identity, and progress in reading can be hindered by OME-related hearing loss as well as weaknesses in working memory (Kindig & Richards, 2000; Seugneuric & Ehrlich, 2005; Swanson & Jerman, 2007). This review will examine the contribution of phonological and auditory processing to reading, and explore how OME may hinder phonological processing and impact on the development of verbal short term memory and working memory. Links between working memory and progress in mathematics and emotional well-being will also be explored.

Research into reading development demonstrates the importance of phonological processing abilities for early reading success (Alcock, Ngorosho, Deus & Jukes, 2010; Anthony, Lonigan, Burgess, Driscoll, Phillips & Cantor, 2002; Muter, Hulme, Snowling & Stevenson 2004). Good grapheme-phoneme skills (Burgess & Lonigan, 1998; Dixon, Stuart & Masterson, 2002; Goodman, Libenson & Wade, 2010; Johnson & Watson, 2005; Stanovich, Siegel & Gottardo, 1997), and working memory capacity (Alloway et al*.*, 2004; Alloway et al*.*, 2005; Alloway et al*.*, 2009; Dahlin, 2011; Gathercole et al*.*, 2004; Loosli et al*.*, 2012; Oakhill & Kyle, 2000) are also important for reading.

According to Torgesen, Wagner and Rashotte (1999), phonological processing comprises three distinct components, phonological awareness, phonological memory and rapid naming. Phonological awareness relates to recognition of different sized units of speech (words, syllables and phonemes) and depends on the child being able to segment the continuous acoustic signal into meaningful units. This skill demands sufficient exposure to language (Kuhl, Conboy, Coffey-Corina, Padden, Rivera-Gaxiola & Nelson, 2008; Nittrouer & Burton, 2005; Robinshaw, 2007) and may have a reciprocal relationship with reading development, as learning letters and sounds focuses attention on speech sounds at the phoneme level (Anthony et al., 2002; Muter et al., 2004).

Phonological memory (otherwise referred to as verbal short-term memory) involves storage of auditory verbal information for short periods of time. Rapid naming refers to the speed and efficiency with which words (such as names of objects, number names or colours) can be retrieved from LTM.

Phonological processing

Some studies suggest that phonological processing, rather than general auditory processing problems, are implicated in reading difficulties (Hornickel & Kraus, 2013; McArthur, Ellis, Atkinson & Coltheart, 2008; Mody, Studdert-Kennedy & Brady, 1997; White-Schwoch & Kraus, 2013). Auditory processing encompasses all sound signals coming in to the ears, while phonological processing refers to the processing of speech sounds. Processing speech requires storage at each stage, therefore verbal memory has a role to play (Cutting & Pisoni, 1978; Hickok & Poeppel 2007). Interference in the perception of speech signals resulting from intermittent hearing loss associated with OME may affect the ability to identify speech sounds (Anderson & Matkin, 2007: Hall, Munro & Heron, 2007; Kindig & Richards, 2000; Maruthy & Mannarukrishnaiah, 2008; Robinshaw, 2007; Winskel, 2006), causing problems with literacy (Dixon, Stuart & Masterson, 2002).

A study conducted in the USA by Mody, Studdert-Kennedy and Brady (1997) examined phonological and auditory processing skills in children with good and poor reading abilities. They recruited 20 poor readers and 20 good readers from a pool of children aged between 7;0 and 9;03, matching the participants for age and non-verbal intelligence. The researchers wanted to find out whether reading difficulties were related to problems with auditory temporal processing (Benasich & Tallal, 1993) or with identification of and discriminating between similar speech sounds, for example *ba/da*. Three experiments were conducted. To begin with, groups of good and poor readers were trained to respond to synthetic presentations of *ba* and *da* by pointing to a coloured dot, and later by pointing to a dot and saying the sound they had just heard. This first experiment was used to select a group of poor readers who made errors discriminating between *ba* and *da*, while subsequent experiments were to find out whether the poor discrimination was due to acoustic or phonological processing. Next, the participants were required to listen to pairs of *ba da* syllables and respond with the order of presentation. Finally, participants were required to listen to two syllables and indicate whether they had heard the same syllable twice, or two different syllables. For the second portion of Experiment 1, poor readers repeated the temporal order and discrimination tasks but were asked to discriminate between *ba* or *da* paired with a syllable with greater phonological contrast. It was found that poor readers made mistakes judging the order of presentation of *ba* and *da*, but not when the syllables were made easier to identify by pairing with a phonologically contrasting sound. This suggested that the difficulty was identification rather than temporal judgement.

Experiment 2 was conducted with good and poor readers to determine whether there were differences between the groups in identifying non-speech sounds, to determine whether the problem was rooted in general auditory processing or in processing speech sounds. For this experiment, the children were trained to respond to pairs of digitally generated sounds which could only be perceived as an upwards or downwards sweep, by pressing buttons marked with up or down arrows. There were no significant differences between the groups on these tasks. Finally, the children were required to listen to digitally generated speech and indicate whether they had heard '*say*' or '*stay*'. Again, the poor readers' performance was not significantly different from that of the good readers. From these results, Mody *et al.* suggested that there was no evidence for the temporal processing deficit hypothesis. Poor readers were no worse than the good readers at discriminating between speech sounds if they were able to identify them, and the rate of presentation was not significant. Poor readers in their study were found to have greater problems than good readers processing speech sounds, that is, in discriminating between similar speech sounds, but not pure tone sounds, thus supporting the idea that poor readers' problems are situated in speech processing, rather than general auditory processing.

The importance of phonological processing to reading development was suggested by Hornickel and Kraus (2013), who measured the phonological processing and single word reading skills of 100 children aged between 6;0 and 13;0 (mean 9;7). All children had normal responses to non-speech sounds. Children were allocated to good, average or poor reading groups according to single word reading scores on the Test of Word Reading Efficiency sight words subtest (TOWRE, Torgesen, Wagner & Rashotte, 1999), with scores for good and poor readers typically one standard deviation above and below the mean. Phonological processing was determined by capturing auditory brainstem responses to speech syllables *ba* and *ga*, via electrodes attached to an earlobe and forehead, while the children watched a film. Results indicated that neural responses of poor readers to identical sounds were significantly less consistent than those of good readers. This means that the same sound was perceived differently on different occasions. Additionally, poor readers showed greater sensitivity to non-meaningful differences in the speech signals than good readers. If the processing of speech sounds is inconsistent, this might interfere with the development of phonological prototypes, leading indirectly to reading difficulties, as proposed in McBride-Chang (1996).

Further work by White-Schwoch and Kraus (2013) involving 26 four year old pre-readers with normal hearing, measured auditory brainstem responses to speech syllables as in the previously mentioned study, together with phonological awareness skills. Children were allocated to a high or low phonological awareness group according to their scores on the Clinical Evaluation of Language Fundamentals Preschool, 2nd Edition phonological awareness subtest (Wiig et al., 2004). Neural responses to the different frequencies of the *d* and *g* portion of each syllable were analysed, and it was observed that children with low phonological awareness did not respond to the difference in signal frequency to the same extent as those with high phonological awareness. The implications of this study are that individual differences in phonological processing at the auditory brainstem level may impact on the development of phonological awareness, and may increase an individual's risk of developing reading difficulties. As well as individual differences in phonological processing, Otitis Media, a common medical condition in early childhood, can cause intermittent hearing loss, impacting on phonological processing (Maruthy & Mannarukrishnaiah, 2008), phonological awareness and reading (Kindig & Richards, 2006; Shapiro, et al., 2009; Winskel, 2006).

Otitis Media with effusion

OME, or 'glue ear, results from a build-up of fluid in the middle ear following upper respiratory tract and middle ear infections. This restricts movement of the eardrum and can cause conductive hearing loss (National Institute on Deafness and Other Communication Disorders, 2010). Estimates of the incidence of OME vary. An indication of the incidence of OME in children in the UK can be gleaned from data collected as part of the Avon Longitudinal Study of Parents and Children (ALSPAC, Overy, Reynolds & Tansey, 2012). More than 1000 were children chosen at random from those born in the last six months of the ALSPAC study, and focused on for middle ear status and changes in word recognition thresholds from 31 to 61 months of age. Data are not available for all children at each time point, but of the 921 children tested at 31 months, 98 (10.6%), had unilateral OME while 96, (10.4%) had bilateral OME. At 43 months, 110 (10.8%) out of 1019 children had unilateral OME, while 117 (11.5%) had bilateral OME. By 61 months, this had decreased to 59 out of 950 (6.2%) of children showing signs of unilateral, and 68 (7.1%) bilateral OME (Hall, Munro & Heron, 2007). This study used tympanometry, with a flat tympanogram as evidence of OME. A study conducted in the United Kingdom by GPs found that the incidence of OME in children aged 0 to 5 months was 5.1%, 6 to 11 months was 17.5%, 12 to 23 months was 28.6% and 24 to 35 months was 30.8% (Ross, Croft & Collins, 1988). In Turkey, a study involving 2,960 children aged between four and fifteen years found that 14.7% of 745 children aged between four and six years of age, and 13.9% of 680 children between seven and nine years of age had OME at the time of examination (Erdivanli et al., 2012). While up to 30% or so of children may have OME at any one time, some children may suffer from repeated episodes while others have only one.

Not all children go on to develop complications related to OME, but approximately 20% of sufferers may still have symptoms two months after the initial infection, while 10% may still be suffering three months later (Winskel, 2006). The situation is further complicated because OME can occur in one or both ears at different times, and recur with different levels of severity. Whether or not a history of early onset OME is linked to problems at school depends on the extent and duration of the accompanying hearing loss, which is not always possible to ascertain with retrospective studies. Some studies, for example, Roberts, Burchinal and Clark-Klein (1995) and Roberts, Burchinal and Zeisel (2002), working with disadvantaged children in the United States, found that any problems tended to disappear as the children progressed through primary school, while other studies have found clear and continuing differences between children with OME and their OME-free peers, and it is to these studies that this review will turn, following a brief explanation of why OME may impede children's learning.

OME and auditory attention and discrimination problems

It has been suggested that problems caused by OME in one or both ears relate to the level of hearing loss experienced, rather than the number or duration of episodes (Whitton & Polley, 2011). Whitton and Polley (2011) reviewed several clinical studies and suggested that "the primary risk factor is whether the afferent sensory signal is degraded during critical periods of brain development." (p. 535), and that OME related hearing loss was related to "a panoply of central auditory system irregularities," (p. 535), which could continue even when OME was no longer an issue. Therefore the difficulties experienced by individual children are likely to relate to the interference to the developing auditory system at the time of hearing loss.

Hearing loss in the first year of life may be particularly harmful for the development of phonological and phonemic awareness, because it may interfere with an infant's perception of ambient speech sounds, even before the child begins to understand language. A review of language development studies conducted by Ruben (1999) suggested that by twelve months of age, infants lose the capacity to discriminate phonemes outside their home language, and that OME during the first year of life interferes with the process of discriminating between similar sounding phonemes, even up to age nine. Work by Kuhl (1991), and Kuhl et al. (2008) suggests that during the first year of life, exposure to language facilitates the ability to segment the acoustic signal into recognisable phonemes through a process where infants develop speech prototypes, which act as 'perceptual magnets', attracting similar auditory representations. This means that acoustic signals can vary, but still be perceived in the same way, for example, phonemes pronounced by different speakers, and speakers with different accents. Over time, prototypes for frequently heard signals will be strengthened, while it will become harder to discriminate unfamiliar speech sounds, for example, those used in a different language. In Kuhl (1991), 32 full term infants aged between six and seven months were conditioned to turn their heads when a continuously repeated phoneme was changed. Conditioning was achieved by rewarding a correct head turn with visual presentation of a toy. Phonemes were digitally manipulated so that the distance in frequency between the exemplar sound and the changed sound was controlled. Responses suggested that phonetically different sounds which were close to the exemplar were perceptually drawn towards it, and perceived as the same. This is important for identification of speech sounds, because the same phoneme may be acoustically different, depending on context, requiring ‘many-to-one mapping’ (Cutting & Pisoni, 1978). For example, *d* followed by *i* has a different frequency to *d* followed by *u*, but is still perceived as the same. It was found that the correlation between infant and adult responses to changing sound stimuli was very high, at .86, suggesting that as young as six or seven months, infants are able to form prototypes of phonemes.

Hearing levels are measured in decibels (dB), as the lowest level at which sounds at each of low, medium and high frequencies can be heard. Hearing loss is classified as mild if between 16 – 25dB and moderate between 26 – 40dB. What this means for the child is that with a hearing loss of just 16dB, and with a speaker more than three feet away, 10% of speech can be missed (Anderson & Matkin, 2007; Robinshaw, 2007). A hearing loss of 20dB will result in difficulties perceiving word endings, unstressed sounds, and problems increase with levels of background noise. As the level of hearing loss increases, more speech is missed or misunderstood, from 25 to 40% of speech at 30dB, to 50% at 40dB. At this point learning phoneme/grapheme correspondences and keeping up with lessons in class becomes problematic. The child is not able to follow the usual classroom discourses and if the teacher is unaware of the hearing difficulties, problems may be described in terms of lack of concentration and attention. Speech and language delays may also be present (Anderson & Matkin, 2007).

While the strength of an auditory signal is measured in dB, it ranges across low, medium and high frequencies measured in Herz (Hz). Appendix A is taken from Dewitt (2012), showing how hearing loss across dB levels and frequencies may affect the ability to perceive speech sounds. According to Maruthy and Mannarukrishnaiah (2008), a history of OME affects the development of the auditory processing system. Their study involved 30 children aged between 3;00 – 5;06 who had suffered from OME between six and twelve months of age, and a comparison group of typically developing children without an OME history. They found that processing at the brainstem level was significantly affected for three year old children in the OME group. Observable differences existed between OME group and comparison group in central conduction time, which was increased for OME group children, and auditory brainstem responses, which were reduced for OME group children. While auditory processing seemed to be affected for the younger children in this study, up to age three, results from the children aged four and five indicated that auditory processing improved with age, and the residual differences in auditory processing between the OME group and comparison group were not significant for four and five year olds.

Hall, Munro and Heron (2007) found similar results when studying word recognition thresholds for children with and without a history of OME, aged between two and five years. They used an automated test where similar sounding names of objects, such as tree/key or plate/plane, were presented digitally to control the dB level. They found that words needed to be presented between 5 dB and 15 dB louder for children with unilateral or bilateral OME to identify them, but by five years of age, there was no significant difference between children with and without a history of OME. The discrimination test used for this study was carried out against a quiet background, so does not necessarily indicate the difficulties children with an OME history might have trying to process speech in noise, as in a normal classroom situation. Particular problems associated with trying to process speech in noise will be discussed in the next section, together with links between OME and language development and an examination of reading and spelling difficulties linked to OME, followed by links between phonological processing and working memory development.

OME and language and literacy development

That language learning requires "a great deal of experience with the acoustic signal" (Nittrouer & Burton, 2005, p. 29), is evidenced by what happens to children's language outcomes when their ability to attend to speech signals is impaired, as in cases of OME. Hearing loss associated with early onset OME has been linked with decreased auditory attention and phonological processing skills, which may impact on language comprehension and literacy acquisition (Kindig &

Richards, 2000; National Institute on Deafness and Other Communication Disorders, 2010; Peer, 2005; Shapiro et al., 2009; Winskel, 2006). Peer (2005) found that 703 out of 1000 dyslexic children in her study had suffered from glue ear. Peer suggested that OME impacts on reading and spelling via phonological awareness and word recognition development. Researchers differ in the definition of early onset for OME, with some reporting a significant effect in children suffering OME before two years of age (Shapiro et al., 2009), while others have extended the critical early onset period to up to three years of age (Kindig & Richards, 2000; Winskel, 2006).

According to Peer, and Shapiro, et al., one of the ways in which OME impacts on learning is that the intermittent hearing loss makes listening to speech for periods of time, and especially with background noise, particularly effortful. This follows the earlier work by Rabbitt (1968, in Mody et al*.,* 1999), which showed that adults with good hearing found remembering lists of words harder as background noise levels increased. Young children may find it difficult to sustain the level of concentration and effort necessary to focus on classroom discourse, particularly if auditory attention skills are poor (Asbjørnsen et al., 2005), and as a result, their learning will be impeded. Work by Piquado, Cousins, Wingfield and Miller (2010), sheds some light on the way attending to speech in noise might interfere with learning. This study was conducted with students aged between 18 and 25 with normal hearing. In this study, word lists were presented at 40dB and one word was partially masked by ‘babble’, set at a level to make the word difficult but not impossible to discern. The study used two types of list, comprised of either related or unrelated words. It was found that masking a word made it more likely that the word would not be recalled, together with those preceding it, and links between the masked and related words were affected. Participants in this study had normal hearing and were only required to recall word lists. According to Piquado et al*.* (2010), recall was affected because attending to the masked word disrupted verbal short term memory. Short term memory failures might account for some of the difficulties experienced by children with OME, and will be discussed more fully in subsequent sections.

The particular difficulties of attending to speech in noise are detailed in Robinshaw (2007), who mentioned that classrooms are not usually designed with optimal acoustic properties and that speech signals have to compete with everyday background noise and reverberation due to large amounts of hard surfaces. She found that normal background noise in a classroom is around 60dB, and most teachers raise their voices to a level of 65dB. This is a good level for children sitting at the front of the class, but as the volume of the speech signal decreases by 6dB at a distance of one metre, and a further 6dB each time this distance is doubled, children sitting two metres from the teacher will perceive the speech signal at 53dB, and at four metres distance the signal will be 47dB, with much of the content masked by background noise. Therefore classrooms are not optimal listening environments for children with normal hearing, and children with intermittent hearing loss who are not seated next to the teacher will be doubly disadvantaged.

The effects of early onset OME on language development have been documented by Ruben, Wallace and Gravel (1999) who conducted a study in the USA. Eighteen Otitis Media free and twelve Otitis Media positive children were followed from birth to age nine. Children were allocated to Otitis Media positive or Otitis Media free groups on the basis of their middle ear status at each of eleven clinic visits during their first year of life. Children who were free from signs of Otitis Media for at least 80% of the visits were allocated to the Otitis Media free group, while children with signs of bilateral OME at 30% or more of the clinic visits were allocated to the Otitis Media positive group. Significant differences were found between the group means on eight language measures, including speech recognition in noise, sentence comprehension and memory, up to age nine.

A large scale longitudinal study based in Dunedin, New Zealand, involving more than 1000 children from birth in 1972-3 to age 26 (Bennett, Haggard, Silva and Stewart, 2001), sampled OME status and hearing thresholds at birth, and then every other year from three to fifteen, then at eighteen, twenty-one and twenty-six. A range of other measures were also obtained, including verbal and non-verbal IQ, reading, spelling, and behaviour rating scales. When the children were five, 8.8% showed evidence of OME, by age seven the figure was 6.1%, and this had fallen to 1.8% by age nine. The main findings of this study were that OME status up to age nine was linked to inattentive behaviour in the teenage years up to fifteen, as well as verbal IQ at eleven and thirteen, non-verbal and full IQ and spelling problems at thirteen, and reading problems from eleven to eighteen.

An Australian study following 43 children with a history of OME aged between six and eight and 43 control children (Winskel, 2006) showed that there were significant differences between the groups on measures of phonological awareness, expressive vocabulary, word definitions and reading, including non-word reading, reading fluency and comprehension, which endured well into the years of primary schooling. In the USA, a study examining the differences between a group of 40 children aged between eight and ten years who had suffered repeated episodes of OME before the age of three and a control group (Kindig & Richards, 2000) found that the OME group means on all measures, including reading and verbal comprehension, were almost one standard deviation below their typically developing peers. Shapiro et al. (2009) found that early onset OME, before 24 months of age, resulted in significant differences between OME positive and OME free nine to ten years olds on reading and phonological awareness assessments. They were also able to identify a subgroup of 14 out of the 24 children in the OME group who had continued to suffer from repeated episodes beyond the age of six and who achieved the poorest scores. Children in their study who suffered their first episode of OME from the age of 25 months onwards did not appear to be significantly different from a group of 20 typically developing children. These results support the theory that there are certain critical periods, during which intermittent hearing loss is likely to have a greater effect on subsequent language and literacy development.

While not specifically focussed on difficulties related to OME, a UK study looking at the relationship between phonological awareness and reading demonstrates the importance of good phonological awareness skills for progress with early reading. This study examined the relationship between the ability to segment initial and final sounds in words of reception class children and their ability to learn to read words (Dixon, Stuart & Masterson, 2002). Performance on phoneme segmentation tasks was used as a measure to separate the children into three groups: those who could isolate initial and final sounds in words, those who could identify the first sound, and those who could not identify either first or last sounds. The children were then trained to recognise words presented in capital letters on flashcards, with more than one word in the stimulus set beginning with a particular letter, so that initial letter cues or word shape could not be relied on for successful performance. After ten training sessions, most children who could initially identify first and last sounds in words were able to recognise most of the words, and learned to read them at a faster rate than children who could identify only first sounds at the outset of the study. Children in the second group had managed to learn only around half as many, or just over four words, while the phonologically unaware group of children had learned to recognise even fewer words and appeared to be making very little progress. Although this study was not connected with OME, the relationship between phonological awareness and reading at an early stage of a child's education was established. Children with poor phonological awareness skills made slow progress with word recognition, despite repeated training, and soon reached a plateau beyond which further training appeared to make little difference.

It appears then that OME related hearing loss can impact on auditory attention and discrimination, making it more difficult to develop stable representations of speech sounds. This in turn can hinder a child's learning of grapheme-phoneme correspondences when trying to map letters onto those sounds. Not all children who suffer from OME become dyslexic, and not all dyslexic individuals have suffered from OME, nevertheless, it appears that a history of OME may increase children's vulnerability within the classroom by interfering with development of the phonological processing system. In the following sections the focus is on consequences of OME for verbal short term memory and working memory, as well as emotional functioning, since these were the areas of difficulty that were addressed with the children in the present study.

Working memory: individual differences

The structure of working memory was briefly outlined in the section on theory; views concerning its structure and function in learning contexts follow. Working memory research often refers to *simple* and *complex* memory span. *Simple* refers to the ability to remember and repeat lists in serial order, while *complex* means that information needs to be manipulated in some way, for example, attended to and recalled against distracting information, such as in the sentences *giraffes have long* ***necks****; tomato soup tastes* ***delicious; ****clowns wear red* ***noses***, where *necks*, *delicious* and *noses* would need to be recalled in the correct order. This type of task is often used to assess listening, or sentence, recall. *Simple* therefore means storage and recall of information, referred to in this study as short term memory, while *complex* means executive control of attention and recall, referred to in this study as working memory.

As previously mentioned, children develop perceptual processes that involve attending to salient details of incoming speech signals, and learning what to attend to and what to ignore, but 'fuzzy' representations of speech sounds cause problems for coding and storage in memory (Nittrouer & Burton, 2005). Children's performance in traditional tasks of phonological awareness (discriminating phonemes in words, segmenting words into phonemes, blending phonemes to make words etc.) may be affected by individual differences in verbal short term memory and verbal working memory, as well as medical issues such as OME. Alloway et al*.* (2013) reported that the range of working memory abilities is very wide in any given class of children, and of the 3189 children screened as part of the Alloway et al*.*'s (2009) study of behavioural characteristics of children with poor working memory, around 10% obtained scores within the deficit range.

As previously described, verbal short term memory, a visuo-spatial sketchpad, and an episodic buffer were identified as separate components of memory for adults, and Alloway et al*.* (2004) confirmed that the structure for young children appears to be the same, based on results from 633 four-to-six-year-olds attending UK schools. The children's working memory was assessed using three measures of complex memory span: backwards digit recall, counting recall and sentence recall. Sentence recall required children to listen to a series of sentences, each with a word missing and supply, then recall, the missing words. Verbal short term memory was assessed using digit and word list recall tasks as well as non-word repetition, and evidence for an episodic buffer was examined using a sentence repetition task. The presence of an episodic buffer was suggested because the number of words which can be recalled and repeated in a sentence is greater than for meaningless word strings, therefore something must exist which integrates information from semantic and syntactic language processing with the contents of verbal memory. Alloway et al*.* tested their data against different models of working memory and found that Baddeley's (2000) modular structure, including an episodic buffer, was the best fit.

Working memory comprises several capacity-limited stores which "support ongoing cognitive activities." (Alloway et al., 2009, p. 606). Specific components of working memory contribute to academic progress at school, for example, recent work by Bourke, Davies, Summer and Green (2013), involving 143 reception aged children from UK schools, suggested that visuo-spatial working memory makes a strong contribution to early writing ability. Bourke et al. argued that this is because it links information about letters and sounds and spelling rules held in LTM and information in working memory for a short time, ultimately requiring refreshing by means of phonological recoding, or translating into verbal form. Five year old children were found to be more affected by the 'visual confusability' of letters than seven year olds. Bourke et al. found that visuo-spatial working memory capacity, as measured by the *Odd One Out* subtest of the Automated Working Memory Assessment (Alloway, 2007), made a unique contribution to predicting writing skills. The *Odd One Out* subtest involves display of sets of three shapes in a 3 X 1 grid for a few seconds. The child is required to indicate the odd ones out. When the sets of shapes are removed from the screen, the child is required to point to the empty boxes on the grid to indicate the correct sequence of odd ones out.

As indicated in the previous section, children with early onset OME have been found to have phonological awareness deficits compared with their peers (e.g. Winskel, 2006) and strong associations have been found between phonological awareness and verbal memory (Hecht, Torgesen, Wagner & Rashotte, 2001). Hecht et al. (2001) suggest that phonological awareness and verbal memory are strongly linked because performance on many phonological awareness tasks depends on being able to hold phonological representations in memory while performing operations on them, such as blending, segmenting, reversing or deleting phonemes. It is worth repeating that children whose phonological processing systems may appear to be no different from those of typically developing peers may still demonstrate differences on a range of measures, depending on the age at which they suffered intermittent hearing loss, as the different parts of the language system develop at different times (Ruben, 1999; Ruben, Wallace & Gravel, 1999). According to Nittrouer and Burton (2005) p. 33

> *"the time course of the effects of early experience may vary. The deleterious effects of deficits in early experiences may fade away (i.e. children might "catch up"), or effects may become apparent only at later ages as children who received appropriate experiences pull ahead of children who did not."*

Therefore, children might suffer from OME related hearing loss at an early age but consequential disadvantages may not appear until later on in their school careers, or may not appear at all if circumstances provide opportunities to repair the earlier damage.

A UK study investigating the relationship between phonological awareness and working memory (Oakhill & Kyle, 2000) found that different phonological awareness tasks relied on different components of the working memory system, with sound categorisation tasks, where children have to find the odd word in a four-word sequence differing by onset or rime, depending more heavily on Central Executive working memory functions than simple storage. In this study, 29 boys and 29 girls aged between seven and eight years were tested on two phonological awareness tasks, a verbal short term memory and a working memory task, as well as a single word reading task. Phoneme deletion tasks required a single phoneme to be deleted from an initial or final consonant cluster. This might at first glance appear to be quite complicated, but results indicated that performance depended to a greater extent on storage than working memory. Verbal short term memory was tested by recalling lists of words, while working memory was examined by supplying a missing word to complete a sentence. Recall of words supplied was tested at the end of each trial. The phonological awareness tasks were found to have high correlations with each other and with reading ability, but once this was controlled for, it was found that the phoneme deletion task, which requires phonemic awareness, made fewer demands on working memory than the sound categorisation task, which also tested phonological awareness at the onset-rime level. Therefore children's performance on different types of phonological awareness task seems to be mediated by their verbal short term memory and working memory, as well as phonological awareness at the level required for each task.

Working memory has also been investigated in relation to reading processes. Seigneuric, Ehrlich, Oakhill and Yuill (2000) carried out a study with 48 French children aged 8;08 to 10;07. Tests of reading comprehension, which examined understanding of syntax, references to *he* and *she* (pronominal references) in text, and making inferences, were administered. Vocabulary was tested by synonym selection, and decoding was examined by reading aloud, recording errors. Five working memory tasks were also administered. Listening span involved supply, then recall, of a missing word at the end of a sentence. Sentences were presented in sets and the missing words had to be recalled in the correct order. Finding the odd-word-out from a set of words involved presentation of sets of four words, three of which were related. The unrelated words had to be recalled in order of presentation. Digit recall involved reading sets of three digits and recalling the final digit in each set in serial order. Number recall required identification and serial recall of the largest number in sets of three numbers. Line recall involved looking at 3 X 3 grids containing two coloured dots. Children had to indicate the third box on the grid to make a line incorporating the two dots. They had to try to remember the position of the lines and the correct colours, and place them on an empty grid following presentation of each set.

It was found that performance on all working memory tasks, apart from recalling coloured lines on a grid, shared moderate correlations, from .41 to .56, with reading comprehension, with the ability to identify and recall the odd-word-out having the strongest correlation. Following multiple regression analysis, vocabulary and odd-word-out scores were found to be equally strong predictors of reading comprehension, and verbal measures were stronger predictors than the numerical measures.

Working memory was found to be associated with children's abilities in maths problem solving by Zheng, Swanson and Marcoulides (2011). They examined working memory and verbal and visuo-spatial storage in 310 American children from Grades 2, 3 and 4, with mean ages approximately 7;09, 8;09 and 9;09 respectively. Working memory was measured using a listening span task similar to sentence recall tasks previously described, and a digit sentence span test, where the children were asked to recall numbers embedded in a spoken sentence. Verbal and visuo-spatial storage were assessed using forward digit span, word and non-word span, and matrix sequence tests, where children were asked to recall the position of dots on a matrix, and to recall and draw on a blank matrix a previously presented route. Measures of word reading, reading comprehension, arithmetic, and maths problem solving, using verbally presented problems, were also obtained. It was found that all three components of working memory (Central Executive and verbal and visuo-spatial storage) made significant contributions to children's maths problem solving skills, and that reading comprehension and computation skills partially compensated for deficits in working memory. Zheng et al. suggested that where reading and maths skills were deployed with greater automaticity, children were able to use poorer working memory skills to better effect.

Swanson and Jerman (2007) conducted a three-year longitudinal study with 84 children, aged between 11 and 17 at the start. Measures of reading comprehension, single word reading, verbal and non-verbal IQ and arithmetic were collected along with measures of working memory. Forward digit span and pseudo-word recall were used to measure verbal storage; backwards digit span, an updating test where children were asked to recall the last three digits of a verbally presented number, and digit sentence span, where they were asked to recall numbers embedded in a sentence after answering distracting questions about the sentence, were used to assess working memory. Measures were obtained on three separate occasions one year apart. The children were divided into four groups: skilled readers with reading abilities above the 45th percentile, reading disabled children with reading abilities below the 25th percentile, children with both poor reading and arithmetic skills and children with poor verbal IQ. Swanson and Jerman found that, over the course of the study, children's working memory developed differently between the groups. Working memory in children with poor reading comprehension showed little growth, while skilled readers displayed the most growth in working memory. No evidence was found that children with reading difficulties had deficits of verbal short term memory, while those with more generalised academic difficulties had deficits in both verbal short term and working memory. Swanson and Jerman suggested that the reason for the strong links between working memory and growth in reading comprehension could be because children with well-developed working memory capacity would have more spare capacity which could be used for storage, while children with weaker working memory skills would struggle to cope with the higher level processing aspects of reading, with little spare capacity for storage. They concluded that working memory, rather than verbal short term memory, underpinned children's reading comprehension progress.

Links between OME and verbal working memory

As we saw above, verbal short term memory capacity varies greatly in the general school population (Alloway et al*.,* 2009), it has been linked to various aspects of language development, such as learning new vocabulary or learning a second language (Majerus, Amand, Boniver, Demanez, Demanez & Van der Linden, 2005), and linked to progress in literacy (Alloway et al. 2005; Bourke et al*.,* 2013; Seigneuric & Ehrlich, 2005). The effects of OME on the development of verbal short term and working memory are not yet clear, as studies have produced discrepant results. Some studies have found links between OME and lower capacity in verbal short term memory (Nittrouer & Burton, 2005), while others have failed to find an association (Brandes & Ehinger, 1981). In the Nittrouer and Burton study, 49 children aged between 4;11 and 5;11 were divided between three experimental groups and one control group. The experimental groups were thirteen children with a history of OME, twelve children from low socio-economic status families, and twelve children from a low socio-economic background who had also had OME. Inclusion criteria for the OME group were seven or more episodes of OME determined from a search of medical records, before the age of three, and for the OME free groups, three or fewer similarly documented episodes. Children were required to have normal hearing at the time of examination, to have articulation skills within the normal range (above the 20^{th} percentile), and to have no apparent intellectual deficits. The verbal short term memory test used in this study was repeating word lists. Children in the OME group made significantly more errors in three and four word lists than children in the control group. This study suggests that verbal short term memory may not develop as efficiently in children with a history of several episodes of OME before the age of three.

Children in the low socio-economic groups participated in fewer tests overall, because the researchers feared that they might be available for only one session. This reduced the amount of data available for children in the low socio-economic groups, but children from low-socio-economic groups are not the focus of the current study, the data available from the OME group and control group in Nittrouer and Burton (2005) make a relevant contribution to this literature review.

Majerus et al. (2005) reported data from 20 eight year old children who had severe and recurrent OME, including intermittent hearing loss, before age three, and 20 age matched controls without a history of OME. Six of the OME group had received speech therapy for OME related language delay, and inclusion criteria for all children in the study were normal levels of intelligence, receptive vocabulary, and normal hearing at the time of the study. The study found subtle differences between the groups on measures of dichotic listening, non-word repetition and rhyme judgement, but when the six children who had received speech therapy were removed, no significant differences were apparent between the groups. Although all the children were within the normal range on all measures used for selection criteria at the time of the study, the children receiving speech therapy were presumably those worst affected by OME related hearing loss during their early years, and although they had apparently caught up with their peers according to standardised tests, some differences remained.

It appears that the evidence for differences in verbal short term memory between children with and without a history of OME is inconclusive, likely due to differences in inclusion criteria between the studies. OME histories of participants may overlap, where uncertainties exist about the number, duration and severity of OME episodes, which is a potential difficulty in retrospective and parental report studies.

Working memory training

As Harold's case study in the next section will show, interventions to address weaknesses in phonological awareness and knowledge of phonics, as well as intensive oral language and vocabulary instruction may not address problems with verbal working memory, which until recently have been thought difficult to remedy (Gathercole et al., 2004). Working memory abilities are distributed in the general population in the same way as other characteristics, and a number of children in any class might be expected to have poor working memory in the normal course of events. As mentioned earlier, links between poor working memory and learning difficulties have been established (Alloway et al. 2009; Kofler et al*.,* 2010; 2011; Gathercole et al*.,* 2004). Kofler et al. (2010) and (2011) were concerned with the effects of Attention Deficit Hyperactivity Disorder (ADHD), which is not included in the focus of the current study. Gathercole et al. (2004) reported strong links between working memory skills and the academic attainments in English and maths of 40 Year 3 children, and strong links between working memory and maths and science attainment for 43 Year 10 children.

In my experience as a class teacher and learning support coordinator, interventions to ameliorate learning difficulties in the classroom are often impeded by children's working memory deficits, leading to repetition of basic material and very slow progress. When teaching young children and observing the practice of my close colleagues over a number of years, adjustments are made to the pace of presentation of new material, and the amount of new material presented at any one time and efforts are made to explicitly link new material with prior knowledge, to suit the characteristics of particular year groups. Physical apparatus and visual aids are available in the infant classroom, and teachers spend time trying to teach children to use metacognitive strategies to aid their learning by modelling thinking aloud strategies and providing opportunities for children to practise them. Listening and recalling information is practised through playful activities. For example, "*I went to the shops and bought…",* where children need to listen carefully to earlier speakers, recall the spoken items in serial order and add an item of their own, and *Kim's Game,* where several small items are displayed on a tray, then covered, to practice visual recall. These, and many other listening and attention games, contribute to children's everyday experiences in the infant classroom. Children's outcomes in these learning situations are usually reported under the umbrella of *Speaking and Listening,* (Department for Education Schools, 2013) and in some settings, such as Bridgeworth School, are not monitored as rigorously as outcomes in other areas of learning, as they are difficult to measure and record. It is likely that in the absence of a suspected or identified learning difficulty, teachers may be largely unaware of the working memory capabilities of individual children, in the same way that OME status may also be unknown.

As it has been shown that working memory deficits are likely to be linked with learning difficulties (Alloway et al*.,* 2009), it is tempting to follow the thought that improvements to working memory might ameliorate those difficulties. An earlier study (Turley-Ames & Whitfield, 2003) examining the working memory capacities and memory and recall strategies used by 124 undergraduate students, found that individuals with low working memory capacity tended not to employ strategies to aid recall. When they were taught to use a rehearsal strategy, their performance improved. The study found that rehearsal was the only strategy which produced improvements for low working memory participants; more elaborate strategies such as visualisation and weaving information into a story were not found to be effective. This research suggested that poor working memory capacity might be ameliorated by allocation of resources to employ retention and recall strategies. Therefore, training to develop such strategies might benefit individuals with poor working memory.

Another UK study by St Clair-Thompson, Stevens, Hunt and Bolder (2010) reported promising improvements in listening recall and mental maths for 127 children aged between five and eight years, using a computerised training programme called *Memory Booster* (Lucid Research Ltd., 2013), which explicitly encouraged the development of working memory strategies, such as rehearsal, imagery, stories and grouping. These ideas follow on from the work of Turley-Ames and Whitfield (2003) mentioned earlier, where training in rehearsal strategies improved the performance of undergraduates with low working memory on recall tasks, but relate specifically to children. One hundred and thirty seven children participated in a control group. The children were recruited from mixed ability schools and whole classes were included. As well as measures of verbal and visuo-spatial working memory, using recall of digit strings, listening recall involving remembering and recalling the last words in sets of sentences, and sequences tapped on blocks, the children completed a following instructions task, where the number of information carrying words was gradually increased, a mental arithmetic test and standardised tests of reading and maths. *Memory Booster* was used for 30 minutes twice a week for six to eight weeks. Significant improvements were achieved for the intervention group for listening recall, mental arithmetic and following instructions, however no improvement was apparent in the children's performance on standardised tests of reading, arithmetic or mathematics. The authors suggested that while improvements related to training transferred to tasks sharing common processes, performance on standardised tests might not depend greatly on working memory processes, therefore improvements may not affect the outcome of these tests.

Infant teaching is full of little rhymes, actions and images to help children develop strategies to remember spellings, letter formation and various secretarial aspects of writing and presentation, however, to participate in lessons and learn these strategies they need to pay attention, listen and look. As previously mentioned, the classroom listening environment may not be ideal, and children's individual abilities to listen and process speech sounds may be compromised by OME. Some children in each class find learning even the most basic skills very difficult, and struggle with letter and number recognition, letter formation, blending and segmenting sounds in words, and setting out their work as modelled to them several times every day, and in my professional experience, several of them had also suffered from OME. As noted by Nittrouer and Burton (2005), I found that children with strong cognitive foundations, built on adequate experience listening to language at home and at school, forged ahead, while others continued to struggle. Strategies had not made a great deal of difference to children's educational outcomes in research contexts and had not proven effective in my professional context either. An intervention which might change the characteristics of children with poor working memory related to early onset OME, by increasing working memory capacity, seemed more promising.

In recent years, several computer-based working memory training programmes which claimed to do just that have been developed, however Cogmed (Klingberg, Forssberg & Westerberg, 2002) working memory training has come to dominate the market. Computer-based training programmes are intensive and time limited, involving drill and practice of targeted skills. The Cogmed programme comes in three versions: JM for very young children, RM for juniors aged seven upwards, and QM for adults. The versions are identical in content, but differ in visual presentation and duration of training sessions. The QM version is plainer, without the built-in incentives and rewards designed to improve children's compliance during training, which are included in the junior versions. The programme is regularly updated to respond to research findings (Gibson, Gondoli, Kronenberger, Johnson, Steeger & Morrisey, 2013). The latest online version (3.1), released in 2013 has a built-in assessment of working memory, following instructions and maths. The assessment is administered during the first session and repeated every few sessions. Standard and beta training protocols can be set, varying the length of each training session and the number of sessions overall. These protocols are recent and were not available during my study or any of the studies using Cogmed reported in the literature review.

The use of computerised working memory training programmes such as Cogmed has been reviewed (Apter, 2012; Morrison & Chein, 2011; Shipstead, Hicks & Engle, 2012) with mixed conclusions. One criticism is that the number and variety of training exercises presented during the programme means that any reported gains cannot be attributed to any one particular activity. Loosli, Buschkuehl, Perrig and Jaeggi (2012) attempted to address this issue by using a programme with only one activity, targeting visuo-spatial working memory. The task involved decision making and serial recall, and is reported in greater detail later. Other criticisms have been largely concerned with weak experimental designs, lack of randomised controlled trials, and lack of specificity when describing exactly what is affected by the training, and how. For Shipstead et al. (2012) the assumptions regarding the structure and function of working memory underlying the design of working memory training programmes, particularly Cogmed, were over simplified and under-specified. Components such as the Episodic Buffer, and primary and secondary stores (Gibson, et al., 2013) were ignored. Shipstead et al. suggested that, given the complexity of working memory, the assessments used to measure working memory capacity before and after training were not adequate for the purpose. According to Shipstead et al. and Morrison and Chein, improvements on these types of task, such as remembering lists and digits, or the positions of dot sequences, could be explained as practice effects of the training or expectancy or effort effects. In their opinion, the lack of active control groups in many studies was a serious limitation, as,

> *"regardless of the procedures used, not a single study conducted to date has simultaneously controlled motivation, commitment and difficulty, nor has any study attempted to demonstrate explicitly (for instance through self-report) that the control subjects experienced a comparable degree of motivation or commitment, or had similar expectancies about the benefits of training."* (Morrison & Chein, 2011, p.55)

If this were to be the case, *near* transfer had not yet been established, and in the absence of near transfer, far transfer to other areas of cognitive functioning was unlikely. Concerns about potentially confounding variables arising from uncontrollable differences between individuals were also raised.

Despite the criticisms, as reported in the reviews, promising trials involving computer-based working memory training (Dahlin, 2011; Holmes et al., 2009; Klingberger et al., 2002; Loosli, Buschkuehl, Perrig & Jaeggi, 2011) had found significant improvements in temporary storage and retrieval of information. Notwithstanding the relevant concerns previously mentioned, it appeared to me, that an intervention using computerised working memory training might be particularly useful for the participants in my study, whose working memory problems might be related to coding and storage issues resulting from interference to the incoming speech signal during their early years. Their working memories might have some residual weaknesses, but might differ from those of children with general working memory deficits and problems with executive functions, as in Alloway et al. (2009).

Klingberger et al. were primarily concerned with children with poor working memory linked with Attention Deficit Hyperactivity Disorder, which is not relevant within my professional context. This review will focus on studies with children more likely to share behaviours and characteristics with some of those at my school.

Holmes, Gathercole and Dunning (2009) screened 345 children attending UK schools and selected 42 on the basis of a score at or below the 15^{th} percentile for verbal working memory assessments, listening recall and backwards digit recall. The children were allocated to two groups: an adaptive (22 children with mean age 10;01) or non-adaptive (mean age 9;09) training group. After selection, children's working memory was assessed using the Automated Working Memory Assessment (AWMA) (Alloway, 2007) on three occasions: before training, immediately after training and six months after training. The AWMA comprises three assessments each for verbal short term memory, verbal working memory, visuo-spatial short term memory and visuo-spatial working memory. Verbal short term memory is assessed by repeating digit strings and recalling lists of words and non-words. Verbal working memory is assessed by more complex tasks involving listening to and making a judgement about the veracity of short sentences while recalling and later repeating the last word of each sentence in the correct order, and backwards digit recall. Visuo-spatial working memory is measured by counting sets of dots and recalling the number in each set in the correct order, and making judgements about the orientation of figures and shapes while recalling the position of red dots. Visuo-spatial storage is measured by recalling the order in which dots are displayed on a 4X4 grid, tracing a previously displayed route out of a maze, and recalling the sequence in which sets of blocks are tapped. Scores are then averaged to produce a separate composite score for each domain. The children were also assessed on a range of background measures including cognitive ability and ability to follow instructions. No significant differences were apparent on any of the measures before training. Mean pre-training AWMA scores for the intervention group were, verbal short term memory, 89.82, verbal working memory, 78.3, visuo-spatial short term memory, 83.36 and visuo-spatial working memory, 80.2. These children's scores were very low compared with the pre-training scores obtained by children in my study, presented in the Participants section of the next chapter. This is to be expected given that Holmes et al. selected their children from mainstream schools on the basis of poor working memory, while children in my study, none of whom had a recognised learning difficulty, attended a highly academic independent preparatory school.

Children in the Holmes et al. study used the RM version of the programme for around 40 minutes each day on consecutive weekdays for five weeks, while the control group, with similar memory problems participated in a non-adaptive version. The adaptive version of the training programme became progressively more difficult as the children's skills improved, while the non-adaptive version offered the same activities, but did not increase the difficulty level from session to session.

The non-adaptive version has been criticised by Shipstead et al. (2012) and Morrison and Chein (2011) for being undemanding. They suggest that the small number of trials of each activity do not promote sustained attention, and because use of the programme does not involve mental effort, non-adaptive programme users might not make any extra effort during post-training assessment, while standard version users would have been trained to try harder.

After training, the mean score for the adaptive group's verbal short term memory had increased by 15 standard score points on the AWMA, verbal working memory by 18 points, visuo-spatial short term memory by 19 points and visuo-spatial working memory by 13 points. Mean scores for the non-adaptive group had improved by 3, 5, 2 and 4 points respectively. However, scores for the background measures were not significantly improved after training for either group. Perhaps the lack of improvement on background measures rebuts motivation and effort criticisms mentioned earlier. 68% of children in the experimental group improved their AWMA scores to an age appropriate level (standardised scores above 95), while 25% of children in the control group achieved a similar improvement.These improvements were clearly visible six months later. This study suggested that intensive computer-based training could increase children's verbal and visuo-spatial storage and working memory, as measured by the AWMA, at least for children with poor working memory to begin with.

A more recent Swiss study by Loosli et al. (2012) involved a short duration computerised adaptive working memory training using the E-Prime software, with 20 typically developing children aged between nine and eleven years, while a comparison group of 20 children closely matched for age, gender and pre training test scores did not receive the training. The study focused on the impact working memory training might have on reading skills, because of the prevalence in the literature of strong links between poor working memory and low academic attainment, particularly in reading, and the authors were hopeful that improvements to working memory, if these could be effected, might help children in the classroom. The training comprised ten sessions in total, from Monday to Friday on consecutive weeks. During each session participants had to make decisions about the orientation of pictures of animals while remembering and later recalling the sequence in which pictures were presented. Each animal had a two syllable name, (e.g. *cam-el*, *zeb-ra*). The training targeted verbal memory, in that the names of the animals had to be stored and subsequently recalled in the correct order, while the spatial decision element was included to increase the complexity of the task, which would otherwise rely on simple storage. Pre-and post-training scores were obtained for three measures of reading: non-words, single words, and text reading (speed and number of errors), as well as in a matrix reasoning task. During training, the treatment group improved working memory span from an average of 3.37 sets to 4.16 sets, or 23%, however Loosli et al. reported large variations within the treatment group, with some children improving very little and others making great strides. Overall, they found that the children with lower initial scores made the greatest progress. Training effects for the treatment group, not shared with the control group, were found to transfer to improvements in reading single words and speed at which text could be read, with fewer errors. Improvement in not non-word reading was not observed.

Dahlin (2011) conducted a study of 57 children with special educational needs aged between nine and twelve years attending Swedish primary schools. The children were split into a treatment group of 42 and a control group of 15. The authors reported that computerised adaptive working memory training using an earlier version of Cogmed (Robomemo), which included the same activities as the current version targeting verbal and visual storage and working memory, improved children's reading comprehension in the treatment group in comparison to the control group, and the greatest gains were seen in the children with the lowest initial scores. Significant improvements to measures of working memory and reading comprehension, with effect size up to *d* .91, were established by pre-test, immediate post-test and delayed post-test six to seven months later. No improvements were reported for single word or non-word reading skills.

In the study of Loosli et al. (2012), contrary to Dahlin's finding, single word reading showed the greatest transfer effect after training. Loosli et al. had expected to find the greatest improvements in reading text, since they reasoned that reading text should place the greatest demands on working memory. However, the assessment of reading they used was restricted to text reading speed and accuracy, which may not have been as sensitive to working memory improvements as the assessment used in Dahlin's, which required children to read sections of text and write answers in a booklet. This type of task may have been more taxing for working memory than reading aloud.

It seems that researcher-led interventions using computer-based working memory training had established grounds for optimism by demonstrating significant improvements in children's working memory and reading in various populations of children, from those with Attention Deficit Hyperactive Disorder, to those with working memory deficits and special educational needs. It remained to be seen whether those improvements might be replicated in an ordinary school, and whether near transfer effects, the direct effects on working memory capacity, could be established and extended to improvements on untrained tasks or academic attainment, thus demonstrating far transfer with significance in the classroom. This would be useful for the children at my school who were struggling compared to their typically developing peers, possibly due to the effects of OME.

Holmes and Gathercole (2013) answered these questions in two trials following 72 children from years 4 to 6 attending UK schools. In the first trial, 22 Year 4 children, with mean age 8;08, completed Cogmed training supervised by their own teacher. Training took place in the computer suite at the start of the school day, with all 22 children training together. A system of rewards and incentives was established by the teacher, in addition to the rewards built in to the programme. Pre-and post-training assessment of working memory using eight subtests from the AWMA demonstrated significant improvements for all areas of working memory, with effect sizes for verbal short term memory, verbal working memory, visuo-spatial short term memory and visuo-spatial working memory of *d* .43, .75, 1.12 and .94 respectively. Some children did not complete all 20 training days, but analysis showed that there was no difference in progress between the children who completed fewer than 20 days training and those who completed a few extra days. There was also no significant correlation between the number of sessions completed and overall improvement.

The second trial reported by Holmes and Gathercole involved 50 children, 25 from Year 5 (with mean age 9:05), and 25 from Year 6, (with mean age 10;06). These children were selected on the basis of low scores on teacher assessments of English and Maths and in school-based tests. The children were matched with an equal number of children from a previous cohort, who had not received working memory training. Following initial tests of working memory and perusal of school records to obtain previous scores for English and Maths, the treatment group children completed Cogmed training led by their teacher. The children's pre-training mean standardised working memory scores were all in the range 100 to 109, which were closer to the scores obtained by children in my study, reported in the next chapter, suggesting that the characteristics of these children might also be closer to those of the participants in my study, than those included in the earlier Alloway et al. (2009) study who were selected for poor working memory. Post-training working memory assessments revealed working memory improvements, with large effect sizes on measures of verbal working memory (*d* 1.34) and visuo-spatial working memory (*d* .78*)* with other effect sizes from .34 to .85*.* Improvements to academic measures showed that the treatment group outperformed the untrained comparison group, with 12% more children in the trained group achieving National Curriculum (Department for Children School and Families, 2009) level 4 in English and maths than the previous cohort. The Year 5 children made greater progress in maths than children in the previous cohort, evidenced by teacher assessment of their attainment across Assessment Focus sublevels (Department for Children Schools and Families, 2010), and Year 6 children performed significantly better than the previous cohort in English and maths.

Finally, Dunning, Holmes and Gathercole (2013) conducted a randomised controlled trial with 94 boys with a mean age of 8;05 and working memory scores determined by the AWMA as falling at or below the 15^{th} percentile. The children were randomly assigned to an adaptive training group, a non-adaptive training group or a no-treatment group. The training groups completed working memory training as previously described for other Cogmed studies. Results indicated that working memory training was effective in effecting significant improvements in visuo-spatial short term memory and visuo-spatial and verbal working memory for the adaptive training group, but while these improvements resulted in stronger performance on untrained working memory tasks, no changes were observed in everyday classroom behaviour.

The working memory training studies reviewed in this section established a rationale for using working memory training with typically developing children falling at the lower end of the attainment range, as well as those with working memory deficits. However, my concerns were not just with children's academic attainment, but with their feelings of self-regard, and the impact of persistent lack of progress compared with their peers on their feelings about themselves as learners. This review will now turn to examination of studies involving children's emotional well-being at school.

Emotional issues

Working memory deficits, and other learning difficulties, have been shown to have wider consequences than the immediate cognitive effects mentioned in the previous section. Research has indicated that there may be effects on emotions, for example, a large scale study involving 308 primary school children aged 5-6 and 9-10 by Alloway et al. (2009), measured a variety of characteristics exhibited by children with poor working memory. The participants were selected from a larger pool of 3189 children on the basis of a verbal working memory score at or below the tenth percentile. When measures of self-esteem were taken, it was found that 39% of the participants obtained low scores in this area, with 12% obtaining very low scores. The assessment instrument used was Insight Primary (Morris, 2002), a teacher rating scale comprising three elements. These are sense of self (individual strengths and weaknesses), sense of belonging (social relationships), and sense of personal power (self-confidence and assertiveness). Scores are obtained for each subscale, and averaged to create an overall self-esteem score falling into one of four ranges: very low, vulnerable, good or high. The results suggested that the children viewed their levels of personal power as low, which meant that they lacked self-confidence and assertiveness, did not think that they would be able to make a difference and were emotionally fragile. The researchers were surprised that levels of self-esteem among their participants were as high as they were, but acknowledged that the measure they used did not specifically address children's self-image in an academic context.

Other studies investigating the effect of anxiety on performance using the framework of Processing Efficiency Theory (PET) (Eysenck & Calvo, 1992) have discovered links between working memory capacity, anxiety and cognitive processing. Processing effectiveness refers to accuracy, while efficiency includes processing speed. In these studies with adults, participants provided ratings of their levels of anxiety and completed working memory tasks. Self-ratings of anxiety at the time of the test were used to separate the participants into high and low anxiety groups. It was found that high levels of anxiety impacted to a greater degree on participants with low to average working memory capacity than on participants with high working memory capacity, in terms of processing efficiency. A recent study by Visu-Petra, Cheie, Benga and Alloway (2011) found that the tendency to worry was present in some children from preschool onwards and was linked with longer response times and poorer performance on verbal working memory tasks than in children without anxiety traits. In a trial involving 116 children aged between 3;01 and 7;04, children were separated into high and low anxiety groups based on parent ratings. Two verbal and three visuo-spatial short term memory assessments were administered. Performance efficiency was determined by accuracy of responses while efficiency was measured by responses times, included preparatory pauses and intervals between words. It was found that while accuracy was not affected by anxiety for these simple, short term memory tasks, children in the high anxiety group took longer to prepare their responses and had longer pauses between words. In a further trial involving 98 children aged between 4;06 and 7;04, verbal and visuo-spatial working memory were tested using elements from the AWMA (Alloway, 2007). To examine verbal working memory, measures of counting recall, listening recall and backwards digit recall were obtained. Visuo-spatial working memory was measured by the *Odd-One-Out* test, and *Mr X*, where a decision has to be made about the orientation of a ball held by a figure on the screen, while remembering the positions of the balls for serial recall. It was found that visuo-spatial working memory was not affected by anxiety, but high anxiety children performed less well in terms of accuracy and speed on tasks involving verbal working memory.

Hadwin, Brogan and Stevenson’s (2005) study involving 30 nine to ten year old typically developing children, with mean age 10;3, found that there were no differences in performance accuracy for verbal and visuo-spatial working memory tasks between children reporting high or low levels of state anxiety. However, in terms of time to complete verbal working memory tasks, children in the high anxiety group took longer, and they reported that some tasks required more effort than for low anxiety participants. Anxiety was measured using the State-Trait Anxiety Inventory for Children (STAIC) (Spielberger, 1973) and effort involved in completing tasks was measured using an adapted version of The Rating Scale for Mental Effort (Zijlstra, 1992).

A slightly later study by Owens, Stevenson, Norgate and Hadwin (2008) involving 50 Year 7 children aged between eleven and twelve, also using the STAIC, examined the children's academic performance, working memory and cognitive abilities. Cognitive abilities were measured using the Cognitive Abilities Test, scores for academic performance were taken from raw scores on English and Maths Standard Assessment Tasks, administered as part of the schools' assessment policies, verbal working memory was assessed using the backwards digit test from the AWMA, and visuo-spatial working memory was measured using the spatial span task from the Cambridge Neuropsychological Test Automated Battery, requiring participants to recall and repeat the sequence of illuminated blocks. Owens et al. found a relationship between verbal working memory and academic attainment, and that differences in verbal working memory accounted for around 50% of the relationship between state anxiety and academic and cognitive ability test outcomes. This means that children with better verbal working memory were less likely to have their academic or test performance adversely affected by anxiety, and that the detrimental effects of anxiety were greater for children with lower verbal working memory capacity. The relationships between visuo-spatial working memory, anxiety and academic outcomes were not significant. The results of this study were consistent with Processing Efficiency Theory and suggest that anxiety places an additional load on verbal working memory, thereby restricting resources which might otherwise be engaged in children's learning.

More recently, Ng and Lee (2010) carried out a study of 114 ten year olds completing maths tasks with and without time constraints. Results confirmed that processing efficiency, but not effectiveness, was affected under time pressure to a greater degree for anxious individuals, but that working memory capacity did not appear to affect the outcomes. This was possibly because the arithmetic tasks used did not tax working memory. Effects on efficiency were determined by the time taken to complete tasks, and effectiveness by accuracy in the tasks.

We have seen how anxiety and working memory might impact on children's academic performance, and how children with low working memory might be vulnerable to low levels of self-esteem. The present study was concerned with examining children's self-concept in an academic context, and exploring their feelings about themselves as learners, including their feelings of safety and belonging within their class and school, which will be discussed in the next section.

I am concerned that children with OME at my school, and perhaps in the wider school population, might be more vulnerable to negative factors impacting on their developing learning identities than their typically developing peers, because when children have poor phonological processing and auditory perceptual skills, or poor working memory, their behaviour may be misinterpreted by teachers as lack of attention and lack of interest. Learning characteristics linked with OME, such as poor auditory attention and phonological processing, slow reading and spelling progress and attention and concentration problems might be misrecognised, potentially affecting teachers' decisions impacting on teaching and learning and access to interventions, as they were in the Alloway et al. (2009) study mentioned above, where teachers described the symptoms of working memory failure in the classroom, for example, inattentiveness, going off task and constant interruptions, but attributed them to other causes.

Learning identity

Repeated negative experiences following on from teachers' misidentification of working memory problems may impact on children's self-esteem and development of a learning identity, and a positive learning identity is crucial for making the most of school based learning opportunities (James, 2008; Pollard, 2005; Pollard, 2007). Identity development has a large literature, but my specific interest is situated narrowly on the effects of cognitive factors, such as working memory restrictions and success or difficulties with aspects of the curriculum, and whether improvements to crucial working memory skills might change the way children feel about themselves as learners.

The concept of identity development refers to the multiple and context dependent identities that people assume in different situations, shaped by prevailing social models (Althusser, 1969; Bibby, 2011; Brooker, 2006; Compton-Lilly, 2006; Hall, 2000; Hirano, 2009; McCarthey, 2002; Pollard, 2005; Pollard, 2007). According to Hall (ibid, p.16) people form identities by a process of "identification … constructed on the back of a recognition of some common origin or shared characteristics with another person or group," so that identities are "points of temporary attachment to the subject positions which discursive practices construct for us." (ibid, p.19). So, rather than going through life with an unchanging sense of self, it is suggested that we constantly redefine our identity by processes of identification with subject positions within certain groups, and rejection of other subject positions which are regarded as undesirable (Brooker, 2006; Compton-Lilly, 2006; McCarthey, 2002).

According to Frosh (1999), "society is a process of control and limitation of the individual in the interests of the group." (p. 41). Schools can be viewed as part of an ideological state control apparatus (Althusser, 1969), influencing parents' and children's desires and expectations. In this view, children are subjects even before birth, as their particular identities are partially shaped by family expectations and social and economic conditions into which they are born. Bridgeworth School is situated in an area which still has grammar schools, and this has impacted on parental expectations about what should be taught, and what represents a successful outcome at secondary school transfer.

Research into children's views of themselves as learners (Bibby, 2008; Bibby, 2011; Compton-Lilly, 2006; Lever-Chain, 2008; Pollard, 1985) suggests that where children experience persistent negative experiences in their learning, due to unsatisfactory emotional relationships with teachers, problems identifying with cultural aspects of curriculum materials, or any other reason, their self-confidence suffers, setting up situations where they are predisposed to fail. Hirano (2009) reported the case of an English language learner who experienced continuing difficulties with his studies because of damage to his self-image as a language student resulting from earlier learning experiences. After work had been undertaken to repair his identity as a language learner, he made greater progress with his language studies. Compton-Lilly (2006) illustrated the ways in which a mismatch between curriculum materials and children's cultural background may also impede their progress. In this study, Devon, a reluctant reader in Year 1, with a keen interest in superheroes, was making poor progress with reading despite participating in a reading recovery scheme. His teacher discovered that a barrier to learning was that he could not reconcile the learning identity of a good student with that of a superhero. When his teacher introduced reading materials about superheroes, which interested him, he began to make good progress.

As noted by Bibby, Moore, Clark and Haddon (2007), in a longitudinal study involving a class of children in a UK school from Year 4 to Year 6, teachers and children may have different ideas about what being a good learner entails. Interviews in the form of on-going conversations with teachers and children revealed that they held conflicting views on what constitutes good teaching and learning environments, strategies, pupil grouping, the nature of knowledge, and children as learners. Teachers' views were influenced by a performativity agenda (Ball, 2003; Ball, 2008) which encouraged them to see knowledge as unproblematic and progress as measurable and incremental, while children were aware that there was more to learning than improving scores on tests. According to Bibby et al. (2007), learning takes place within, and depends on social relationships, which are subject to tensions between social and individual interests.

Tensions and potential conflicts of interest are in evidence at Bridgeworth School, where teachers must balance the needs of individual children who might require a slower pace and more repetition and practice, against the necessity of achieving certain curriculum goals within specific time frames. The difference in teacher/pupil perspectives and resulting tensions are illustrated by the following portrait of Harold, whose particular learning difficulties led me to an interest in OME, its effects on working memory, and what, if anything, could be done about it.

The problem in context: The trouble with Harold

I have been following the progress of Harold (pseudonym) born in December 2003, an early onset OME sufferer, from admission to school in September 2007, aged three. Harold's mother reported that she had had problems with literacy and maths at school, and his younger sister, born in 2007, has suffered from severe bilateral OME following antibiotic-resistant infections, from infancy to the present day. All information presented is based on parents' report. Harold was hospitalised following a severe middle ear infection with a fever at six months of age, after which he was prone to OME for the next two years. Parents were not told that the ear infections could affect his hearing or speech and language development. He has exhibited a range of language and literacy problems at school, as well as difficulties with aspects of mathematics. His problems are described in the following case study, with reference to studies mentioned in the literature review.

Case study

At age three, Harold's speech was indistinct and his use of language was not as well developed as that of his peers at school. This is in line with findings from studies of children with a history of severe and recurrent OME, showing that it can affect the development of conceptual or semantic knowledge systems as well as phonological awareness and vocabulary (Kindig & Richards, 2000; Winskel, 2006). Harold suffered frequent falls at school resulting from poor balance, and it has been noted in a study that children's balance can sometimes be affected by OME (Peer, 2005). While in the Nursery, Harold's language skills were tested on two occasions using the Renfrew Word Finding Vocabulary Test (RWFVT) (Renfrew, 1995) and the Renfrew Bus Story Test (Renfrew, 1997). The RWFVT tests the ability to name objects while the Bus Story Test requires the child to retell a short story with the aid of picture strips. Harold showed by his gestures and descriptions of objects on the RWFVT that he knew what they were but was unable to name several common objects. In conversational speech he seemed to be lacking in sentence complexity and conjunctions.

Aged nearly four, Harold had no measurable phonological awareness skills, when tested with the assessment included in the Sound Linkage programme (Hatcher, 2000*).* By the summer of his Nursery year, he could blend two syllables to make a word, but remained unable to carry out the tasks of rhyme identification, or isolating sounds in words. Harold was seen by the Local Authority Speech and Language Therapy Service at this time and immediately discharged with an advice sheet informing parents how to encourage him to increase the mobility of facial muscles and strengthen mouth movements. His hearing was tested shortly after entry to the Reception class at age four, when his left eardrum was found to be scarred. A follow-up examination by his GP involving inspection of the eardrum one year later, when he had just entered Year 1, was normal.

Harold had been making very slow progress in all areas of literacy and maths at school during his time in Reception and the first term in Year 1, and an intensive intervention involving one-to-one tuition was put in place from the middle of Year 1. This targeted identifying and isolating sounds in words, blending and segmenting, mapping letter patterns to sounds, instructional reading and guided writing. As Shapiro et al. (2009) and Robinshaw (2007) noted, the level of background noise in a normal classroom would make listening and paying attention difficult. The Reception and Year 1 classes at my school have always been busy places, with lots of activities going on at the same time, and background noise is often an issue. Harold would have been unable to focus on the teaching until he was given one-to-one provision, where speech would have been clearer for him and distractions reduced.

Harold's school experience

By the end of the Year 1 Autumn term 2009 it was clear that Harold was falling further behind his peers and was not making satisfactory progress in any aspect of literacy or maths. He achieved the lowest score in the year group on a test of single word reading (Schonell, 1974) and a similarly poor result in all other school-based tests. At this time Harold's teachers complained that he was lazy and inattentive, and that his parents helped him too much with his homework. After consulting with his parents, language, reading and phonological awareness assessments were carried out. The results of language assessments administered are shown in Table 1. Language tests administered previously in Nursery and Reception class are also shown.

Table 1: Results of cognitive, language and reading assessment results for Harold from 2007 to 2010

Test	***Date***	***Standard score***	***Percentile rank***	**Comment**
Wide Range Intelligence Test (WRIT)	February 2010			Performance on Diamonds subtest was slow and some puzzles were solved out of time.
Matrices		89	23	
Diamonds		82	12	
Visual IQ		83	13	Semantic knowledge displayed for some vocabulary items insufficient to score points
Vocabulary		81	10	
Analogies		86	18	
Verbal IQ		82	12	
General IQ		80	9	
Comprehensive Test of Phonological Processing (CTOPP)	February 2010			Could hear first but not last sounds in words, could mimic and copy rhythm and pattern of speech, more consistent with consonants than vowels
Elision		90	25	
Rapid colour naming		95	37	
Blending words		105	63	
Sound matching		95	37	
Rapid object naming		85	16	
Memory for digits		76	5	
Nonword repetition		115	84	
Blending nonwords		100	50	
Phonological awareness		96	39	
Phonological memory		94	35	
Rapid naming		88	21	
Test of Word Reading Efficiency (TOWRE)	February 2010			Could decode only one nonword, ip, displayed no effective decoding strategies. Could produce single sounds but not blend them together, e.g. i-g → git
Sight word efficiency				
Phonemic decoding efficiency		94	34	
		98	45	
NFER Progress in English 6	June 2010	103	58	
Expressive Vocabulary Test (second edition) (EVT-2)	June 2010	112	79	
	September 2009	106	66	
Renfrew word finding vocabulary test (RWFVT)	November 2007	-	53	Semantic knowledge displayed for several items but not names
	June 2008	-	49	
Renfrew Bus Story Test (BST)	November 2007		8	Average sentence length of five words in 2007 increased to six in 2008, no complex sentences or conjunctions used
	June 2008		38	

Harold’s scores on all elements of the Wide Range Intelligence Test (Glutting et al., 2000) were low, with no significant difference between verbal and visual subscales. He also achieved the lowest Early Years Foundation Stage Profile (Department for Children Schools and Families, 2008) score within his cohort. His overall Early Years Foundation Stage Profile score of 84, while above the minimum 78 points required to indicate barely satisfactory progress (London Borough of Bexley, 2008; Matheson, 2008), showed poor progress within the Early Learning Goals for *Numbers as Labels and for Counting* and *Calculating*, while he did not reach the Early Learning Goals for *Writing*.

According to his scores on the Renfrew Bus Story Test, he made good progress between 2007 and 2008 in connected speech production. His performance on the Expressive Vocabulary Test -2 (Williams, 2007) in September 2009 was well within the average range.

Harold's phonological memory and phonological awareness as measured by CTOPP in 2010 were not particularly poor, both above the 30th percentile, but memory for digits was very poor, at the 5th percentile. He displayed no useful phonological segmenting or blending skills during these tests, and his decoding, as measured by the non-word reading TOWRE subtest was very poor. His performance revealed the difficulty in relying on standardised tests to make judgements about children's progress at this early stage of schooling, as decoding just one word between the ages of 6;0 and 6;05 is awarded a standardised score of 98, and it is not until age 7 that it is possible to be awarded a score of less than 85. Notwithstanding satisfactory standardised TOWRE scores, as teachers with experience of working with several cohorts of Year 1 children, his class teacher and I were concerned that his progress was remarkably poor at that time. It is likely that his weak verbal memory made use of grapheme-phoneme conversion to process letter strings and blending phonemes to make words an effortful process, resulting instead in reliance on a guessing strategy, and he did not notice when the retrieved word did not fit the context. This suggests that lexical and non-lexical processes for reading were not developing satisfactorily (Coltheart et al., 2001). Retrieval from LTM, demonstrated by rapid object naming in the CTOPP, was also below average, and he demonstrated many of the characteristics and behaviours of children with poor working memory noted by Alloway et al. (2009).

Harold's expressive vocabulary scores, as assessed by the Expressive Vocabulary Test fell at the lower end for the cohort at the beginning of Year 1 and improved steadily throughout Key Stage 1. At both testing times, his standardised scores were above the national average for children his age, with standardised scores of 106 and 112 respectively. This does not accord with the characteristics of children with poor working memory in Alloway et al. (ibid), where it was found that low working memory was generally linked with poorer vocabulary than was the case with typically developing children. However, at Bridgeworth School a robust vocabulary intervention (Beck et al., 2002) had been in place throughout Harold's Reception year, and previously he had experienced a storytelling curriculum in Nursery, where oral language was prioritised, which could have helped Harold to make good progress in this area.

The intervention

Harold received an intervention from March 2010 onwards, when it was clear that he was not making satisfactory progress in any aspect of literacy or numeracy within normal whole class lessons. The intervention was based on Shapiro and Solity's (2008) suggestions for optimal whole class reading instruction, although implemented on a one-to-one basis (see Table 2). Read Write Inc. (Miskin, 2006), starting with Ditty Books packs 1 and 2 and progressing to reading books Set 1 and beyond, was used to provide words for oral blending and segmenting, letters and sounds practice, sight word and reading practice. The intervention took place before and after school, ensuring that background noise was minimised.

Sessions began with short periods of oral blending and segmenting taken from the Speed Words section at the rear of each reading book, followed by Speed Sound practice, encouraging rapid and automatic response to letters. Speed Sounds involves saying aloud consonant and vowel patterns, with all graphemes representing the same sound presented together in the same column on the page. This was followed by decoding regular words and learning high frequency irregular words, followed by reading practice using words already encountered in context, writing those words and phrases in context and a small amount of handwriting practice. As Harold progressed through the scheme, explicit instruction relating to morphemes, root words, prefixes and suffixes were introduced. Table 2 shows how the intervention progressed during Year 1.

Table 2: Year 1 Intervention for Harold

	Literacy Intervention – supplementary to whole class lessons with class teacher
Frequency and Duration of Sessions	*Implemented by Support Teacher and Parents, one to one* *From Spring half term to end of Spring Term*: Three 30 minute sessions before school each week on Tuesdays, Thursdays and Fridays *First half of Summer Term:* Three 30 minute sessions before school as before plus one hour after school on Thursdays *Second half of Summer Term:* Three 15 minute sessions before school and one hour after school *Early morning sessions observed and repeated in a shortened form at home by parents, additional individual reading from reading scheme books supported by parents*
Structure of Sessions	*Timings approximate and flexible* *Spring and first half of Summer Term (30 minute sessions)* One or two minutes oral blending and segmenting Two or three minutes decoding regular words Two or three minutes learning high frequency irregular words Two or three minutes learning to spell high frequency irregular words One or two minutes responding to letters at speed (Speed Sounds) One or two minutes explaining and working on a new letter/sound combination Five or six minutes reading instructional text Two or three minutes handwriting practice Remaining time (5 – 10 minutes) spent playing phonics pairs games *Second Half of Summer Term (15 minute sessions)* As above with shortened timings for blending, segmenting and letters and sounds, focusing on decoding strategies for longer words, learning high frequency words, reading in context, writing sentences to dictation and longer writing tasks

The Read Write Inc. scheme was used as the published materials provided an alternative to spending a considerable amount of time planning and preparing materials for each session. The division of words into regular and irregular sets, with dots printed under single sounds and dashes under digraphs and other longer vowel graphemes provided a strong visual indication to Harold as to the number of phonemes each word contained, and simplified the decoding process for him.

To begin with sessions were enlivened using pairs games to reinforce new letter patterns and Harold was allowed to use attractive glass beads as counters to help him count phonemes in words. From summer half term, games and motivating activities were discontinued as he was able to maintain his attention and concentrate without incentives. During the one hour session after school, half the session was devoted to maths activities, using number rods and counters as visual aids to teach number bonds, working on number relationships within ten.

Harold's mother participated in several early morning and after school sessions and was trained to use the Read Write Inc. Ditty and reading scheme books so that sessions could be repeated in a similar form at home, helping Harold recall and revise his learning. It is not possible to state with certainty that home sessions were repeated every day, although to my knowledge, Harold's mother was diligent in supervising and supporting homework, and contact books were always signed on a daily basis, with comments where appropriate. In this way, he received two high quality literacy sessions a day for at least three days a week, sometimes more and sometimes less, where absence due to sickness or staff meetings disrupted the sessions. He continued to participate in undifferentiated whole class literacy lessons in his Year 1 class and to take Oxford Reading Tree Stage 3 and 4 books home.

Harold's progress during the intervention

Harold rapidly progressed through the Ditty Books, at the rate of about three per week. After three weeks of Ditty Books he began Set 1 reading books. Progress was slow, but by Set 3, reading had improved so that he was able to read the stories fluently at the first attempt, and by the beginning of Set 4, he was able to read and spell all words encountered to dictation. By June 2010, Harold was reading fluently at first sight from Oxford Reading Tree Stage 4, and achieved a standardised score of 103 in the NFER Progress in English 6. The intervention continued throughout Year 1 and Year 2.

Continuing issues

The intervention appeared to result in an improvement in literacy performance from a level where Harold was unable to participate meaningfully in whole class lessons to the point where he was still at the lower end of the average range, but coping and working independently. Changes in phonological processing scores assessed with the CTOPP test, and single word and non-word reading, assessed with the TOWRE, between February 2010 (just before the start of the one-to-one intervention) and a year later in March 2011, are shown in Table 3.

Table 3: Results for phonological processing and single word and non-word reading for Harold in February 2010 and March 2011

Test	***Standard Scores February 2010***	***Percentile Rank February 2010***	***Standard Scores March 2011***	**Percentile Rank March 2011**
Phonological Awareness	96	39	106	65
Phonological Memory	94	35	88	21
Rapid Naming	88	21	103	58

The weakness in the area of phonological memory appeared to continue to impact on Harold's reading comprehension, writing composition and progress in mathematics, as assessed by his teacher, and to cause him some distress. Harold had some insight into his problems and was sensitive to any differences in treatment he received from the teacher within the class. He refused to use different planning aids, such as cue cards which may have helped him to organise his writing, nor would he use physical apparatus in maths, because the other children did not need it. He often asked if he was doing the same as the other children.

While working with Harold, my role within the school in learning support has brought to my attention a number of other children, from Reception to Year 6, with similar phonological processing profiles, similar responses to intervention and equally distressed parents. A common link between many of the children appeared to be a tendency to suffer from OME in infancy, sometimes continuing throughout early schooling.

Research focus

My experience of working with Harold and his parents highlighted that phonological awareness and phonics training, while making a difference to reading, and in Harold's case, spelling, might not bring about change to verbal short term and verbal working memory. This means that while phonological decoding skills improve, so that children are able to tackle new words in reading, problems processing complex oral or written sentences and planning written work remain. While Harold could decode single words reasonably well following phonics training, when reading text he was still using the strategy of guessing unfamiliar words using first letter, word length and context cues. This is because his decoding was still slow (likely due to verbal memory limitations) and the time taken to decode interfered with fluency, causing him to forget the gist of a story. The persisting difficulties seemed to present challenges in reading, writing and maths, which resisted our combined best efforts. This was a distressing situation for Harold and his parents, and for the other children at the school with similar profiles.

The current study set out to add to existing knowledge about links between weaknesses in working memory and an early history of OME. It looked first for evidence of whether working memory had developed differently in children at my school with a history of early onset OME, and secondly, this study made an original contribution to knowledge about the development of working memory in children with a history of OME by examining the effects of an intervention targeted specifically at working memory. The study also sought to extend understanding and make an original contribution to knowledge regarding the self-esteem of children with lower working memory capacities than their peers (Alloway et al., 2009), by examining the children's self-image specifically in an academic context. It was thought that the inclusion of a focus on children's 'learning identities' and thoughts, feelings and experiences linked to their learning might lead to new knowledge in this area, as this had not been addressed in earlier studies concerned with improving working memory through computer-based training.

To address the concept of learning identity, the Pupil Attitudes to Self and School (PASS) rating scales (W3 Insights, 2011) was used. This assessment tool was selected because it has been designed to measure children's attitudes to learning and feelings about themselves as learners specifically in an educational context. It allows a number of self-rated aspects of learning and motivation to be explored, including whether the children believe they have the 'tools' to enable them to learn, perceived learning capacity, general work ethic, confidence in learning, self-regard, response to curriculum demands and attitudes to teachers. If children with OME were observed to feel less positive about themselves as learners than their typically developing peers, this study sought to make an original contribution to knowledge about children's identities as learners by examining which specific aspects of learning identity might be impacted, and the changes a working memory intervention might have on these feelings. The questions shaping the study are outlined below.

Research questions

Are working memory capacities of children in this study with parental report of early onset OME different from those of their typically developing peers?

What are the effects of working memory training on working memory, phonological abilities, reading skills and other academic achievements?

Are working memory abilities linked with children's learning identities and attitudes to learning in this study?

What are the effects of working memory training on children's learning identity and attitudes to learning?

Chapter 3: Methodology

Introduction

The study aimed to investigate the extent to which early onset OME-related hearing loss may be linked to working memory limitations by 1) examining for differences in working memory between a group of children with early onset OME and a comparison group of typically developing children attending the same suburban independent preparatory school, and 2) seeing whether any differences could be ameliorated by working memory training. In addition, the aim was to look at differences between the groups in terms of learner identities and to see whether the intervention may impact on these. The study had a mixed design with some fixed design features relating to the collection of quantitative data. Quantitative data in the form of assessment scores, standard scores and survey results were collected according to a pre-determined schedule (Robson, 2002). Fixed designs are more suitable for quantitative data, while case studies may require integration of data from a variety of sources.

Quantitative data were used to examine potential differences in assessments of verbal and visuo-spatial short term memory and working memory and in phonological processing and single word and non-word reading and academic achievement for the OME and comparison group. The data were collected at three time points – before intervention, then immediately after, and six months after intervention. In order to assess learner identities a Pupil Attitude to Self and School survey (PASS) (W3 Insights, 2011) was administered to all the children at the beginning and end of the study. Qualitative data were collected during semi-structured interviews with the children. The aim of the semi-structured interviews was to elaborate the findings of the PASS survey. It was hoped that use of different types of data collection method would also increase the validity of the findings. Full assessment details and the schedule of data collection are provided in Table 6 in the section on Data Collection below.

Methods used in previous studies

Studies investigating effects of OME covered in the literature review recruited participants with OME, often via medical records, with control group children recruited from local schools (Kindig & Richards, 2000; Majerus et al. 2005; Winskel, 2006). For the Winskel study, recruitment was based on medical records and parents' recall of OME. Criteria for inclusion in the OME groups in the studies of Kindig and Richards and Winskel were at least four episodes before age three, and the Winskel study also recruited children with fewer OME episodes in the case of treatment with grommets (aeration tubes surgically inserted into the eardrum). The criteria for inclusion in the study of Majerus et al. were: severe and recurrent OME including significant hearing loss for at least three months and at least one insertion of grommets. Nittrouer and Burton (2005) required seven episodes of OME documented in medical records before the age of three, and three or less episodes for inclusion in the control group. The inclusion criteria for the current study relied exclusively on parents' report regarding previous OME status, notwithstanding that this may or may not be completely reliable, as discussed in Brody et al. (1999) and Rosenfeld et al. (1998).

For this study, my reasons for relying on parents' reports were that a request for extracts from medical records might have been regarded as unduly intrusive. Where information about OME is sought retrospectively, it may be difficult to ascertain the specific criteria used for diagnosis, which is not always straightforward. Each recalled episode of OME diagnosed by a doctor was likely to have been accompanied by some hearing loss, even though the severity and duration remained unknown.

Studies investigating the effects of working memory training have employed a variety of assessments to measure working memory before and after training, however many of them have used similar types of tasks drawn from different test batteries to examine simple and complex memory span. Several studies investigating the effects of working memory training using the Cogmed programme (PsychCorp, 2011), that was employed in the present study, have involved use of the Automated Working Memory Assessment (AWMA) (Alloway, 2007) to assess any change as a result of intervention, with delayed post-tests to assess for maintenance of any observed gains (Alloway et al., 2009; Dunning et al., 2013;

Holmes et al., 2009). The present study also used the AWMA, in order to be able to compare results with similar studies, and employed the same intervention design as the studies of Dunning et al. and Holmes et al.

Participants and inclusion criteria

OME group

The participants in the OME group were eight boys and eight girls attending Bridgeworth School, aged between seven and ten years at the start of this study (mean age =8;05, sd=1;01). OME group participants were selected because they had a history of OME diagnosed by a doctor, according to parental report. Seven children, Harold, Mark, and Lucy in Year 3, Cheryl in Year 4 and Nathan, Victor and Ryan in Year 6, were recruited by direct invitation as their OME status was known at school. A further nine children, Melvin, Gerry, Emily, Sally and Leah in Year 3, Brad and Jenna in Year 4, Tyler in Year 5 and Angel in Year 6, were recruited following a letter of request circulated to parents. Two volunteers were excluded from the study because they were too young to participate in working memory training, and a further two children in Year 3, who were initially invited to participate, declined to do so. Brief case history details of the children in this group are presented in Appendix E.

Comparison group

Also participating in the study was a comparison group, comprising five boys and seven girls drawn from Bridgeworth School, mean age 7;11, sd=0;10. The comparison group was included to see if there were differences in working memory between the OME group and typically developing children free from a history of OME, and whether a history of OME impacted on children's feelings about themselves as learners. The comparison group children were selected to differ from the OME group children on OME status only. They were matched to the OME group in terms of age and in terms of general ability, using the non-verbal reasoning assessment – Raven's Standard progressive Matrices (Raven, 1992). Initially, there were seventeen children in the comparison group but during the course of the year in which this study ran, three boys and two girls, all from Year 3, dropped out. Of the remainder, four boys and six girls were in Year 3 and one boy and girl were in Year 5. As far as parents were aware, children in the comparison group had not suffered from OME. Children in the comparison group completed the same assessments as those in the OME group and also took part in the working memory training.

Pre-training scores were obtained for the children in the two groups on measures of academic achievement, reading, phonological processing and memory. A description of all the assessments used is given in the Materials and Procedure section that follows. The measures obtained were for school-based maths and English assessments, phonological processing assessed by CTOPP subtests, single word and non-word reading assessed with the TOWRE, and working memory scores assessed with the AWMA. A summary of the results of the assessments is given in Table 4, together with results for the two groups in the non-verbal reasoning test. Independent *t*-tests were used to look for group differences in the scores. The results of these are reported in the table.

Table 4: Pre-training mean standard scores on the assessments for the two groups of children (standard deviations in parentheses)

Assessment	***OME Group***	***Comparison Group***	***p value (2-tailed)***	***Cohen's d***
Raven's Standard Progressive Matrices	12.19 (4.55)	11.33 (2.57)	.565	.23
Progress in English	99.81 (12.51)	107.08 (6.84)	.081	.72
Progress in Maths	102.19 (11.75)	108.17 (10.22)	.171	.54
CTOPP				
Phonological Awareness	103.94 (9.50)	113.25 (12.30)	.032	.85
Phonological Memory	95.69 (10.10)	104.00 (11.18)	.050	.78
Rapid Naming	103.56 (10.63)	104.00 (8.89)	.909	.04
TOWRE				
Sight Word Reading Efficiency	108.56 (9.93)	112.25 (8.69)	.255	.39
Phonemic Decoding Efficiency	101.38 (10.68)	111.83 (13.07)	.028	.88
AWMA				
Verbal Short Term Memory	98.43 (16.05)	111.99 (12.89)	.024	.93
Verbal Working Memory	94.56 (11.62)	108.41 (15.11)	.011	1.03
Visuo-spatial Short Term Memory	106.94 (15.25)	120.75 (14.13)	.022	.94
Visuo-spatial Working Memory	102.63 (13.25)	115.25 (9.55)	.011	1.09

The results revealed significant differences in favour of the comparison group for all the subtests of the AWMA memory assessment. In addition there was a marginally significant difference in favour of the comparison group for Progress in English scores, similarly for the phonological memory subscale of the CTOPP. There were significant differences in favour of the comparison group for non-word reading in the TOWRE and for phonological awareness in the CTOPP. The results indicate that although the groups were matched on general (non-verbal) cognitive ability, the OME group were impaired relative to peers in memory processes and in phonological processing skills. The results are in line with the findings reviewed in the previous Chapter, indicating impaired memory and phonological processes in children with OME.

The dissociation observed in results for reading skills (poor performance in non-word but not sight word reading) for the OME group appears anomalous at first, but is explicable in terms of the DRC model outlined in the Theoretical Frameworks section. That is, non-word reading is heavily reliant on phonological processing skills, which are impaired in the OME children, presumably as a result of the intermittent disruption to auditory input, while successful sight word reading can be achieved using partial decoding skills supplemented by input from semantics. As noted, the children at Bridgeworth School were exposed to a curriculum that involved boosting early language and vocabulary skills, so it is likely that these skills served to support sight reading.

No-training group

Also participating in the study was a no-treatment comparison group comprising six children from Year 2 (mean age=7;05, sd=0;03) This group was included to see if there was any evidence of change in scores over the time period that the working memory training took place. If there was evidence of improvement in scores due to retesting on the assessments used in this study, then any change in scores observed in the children who took part in the training could not be attributed solely to the intervention. The children in the no-training comparison group were selected to be comparable to the children in the OME and comparison group for chronological age and general ability. None of the children in this group had a history of OME. The assessments of phonological processing, reading and working memory were administered in April 2013 (Time 1) and June 2013 (Time 2). All volunteers were achieving within the average range in their class. A summary of the scores is given in Table 5.

Table 5: Time 1 and Time 2 mean standard scores on the assessments for the no-training group (standard deviations in parentheses)

Test	*Time 1 April 2013*	*Time 2 June 2013*	*p values (2-tailed)*	*Cohen's d*
Raven's SPM	13.33 (2.73)	N/A		
CTOPP				
Phonological Awareness	125.67 (10.61)	128.67 (11.06)	.111	.27
Phonological Memory	120.67 (9.58)	124.50 (9.75)	.074	.39
Rapid Naming	103.00 (9.49)	101.50 (3.15)	.681	.21
TOWRE				
Sight Word Reading Efficiency	115.83 (2.71)	117.33 (2.50)	.060	.57
Phonemic Decoding Efficiency	110.50 (5.92)	109.83 (5.25)	.679	.11
AWMA				
Verbal Short Term Memory	116.33 (10.27)	118.17 (2.86)	.650	.24
Verbal Working Memory	108.83 (10.91)	107.33 (13.66)	.448	.12
Visuo-spatial Short Term Memory	129.99 (7.77)	125.33 (3.93)	.159	.75
Visuo-spatial Working Memory	119.33 (10.23)	124.67 (5.43)	.077	.65

Although inspection of the table indicates an increase in some of the scores, others decreased, and none of the changes were significant.

Materials and Instruments

At the start of the study, Raven's Standard Progressive Matrices (SPM) (Raven, 1992) was used to match the OME and comparison groups on general ability. Raven's SPM was selected as it had been used in several of the studies mentioned in the literature review, and it was thought that its non-verbal format would not disadvantage children whose language skills might have been delayed by OME-related hearing loss, in relation to their typically developing peers. Once this was done, scores were obtained for the OME and comparison group for Progress In Maths (Clausen-May et al., 2004), and Progress In English (Kirkup et al., 2006). These are standardised tests that were administered as part of the school assessment procedure in the summer of 2011 (prior to the working memory training) and at the end of the study in the summer of 2012. They were administered to whole classes according to the school's assessment timetable.

Further assessments were selected for the purposes of the present study and they were administered before the working memory training, immediately after and then six months after. For these, phonological processing was assessed with subtests from the Comprehensive Test of Phonological Processing (CTOPP, Wagner et al., 1999). For this study, participants completed the elision and blending phonological awareness tasks, the memory for digits and non-word repetition phonological memory tasks, and digit and letter rapid naming tasks. This assessment was selected to examine differences in phonological processing between the OME group and comparison group before training, including the phonological awareness skills of blending and segmenting phonemes, phonological memory, and rapid retrieval of phonological information from long term memory, as well as any changes to these skills after working memory training. Therefore relationships between phonological awareness, working memory, rapid naming and single word and non-word reading could be explored before and after working memory training, to determine if children with a history of OME had been disadvantaged in these areas compared to their typically developing peers.

Single word and non-word reading were assessed using the Test of Word reading Efficiency (TOWRE, Torgesen et al., 1999), to measure differences in the efficiency of lexical and non-lexical processes between the groups as specified in the DRC model of single word reading (Coltheart, 2006), before and after working memory training. The extent to which OME related hearing loss had impacted on the development of non-lexical and lexical routes to reading was of interest in this study.

Working memory was assessed using the AWMA (Alloway, 2007). The Pupil Attitudes to Self and School Survey (W3 Insights, 2011) was used to collect the children's self-ratings on feelings about self and school prior to the training and at the end of the study. It was selected because it provided information about children's self-image and well-being specifically in a school context. Children with OME were likely, based on previous research mentioned in the literature review, to have poorer phonological awareness skills and to be behind their typically developing peers in reading. Research into Processing Efficiency Theory suggested that children with poor working memory were more likely to be vulnerable to the effects of anxiety. Therefore it was of interest in this study to see if perceived or observable difficulties in reading or working memory impacted on children's general feelings of belonging, self-regard and group cohesion within school, or if the impacts were more specifically focused in areas of learner confidence, or their metacognitive understanding of their current skill levels, and the match between these and the work set in class. PASS provided information about children's feelings and attitudes in these areas, and as the survey could be repeated at intervals, it would be possible to identify changes in attitudes, and examine relationships between these changes and those observed in children's phonological processing, reading, decoding and working memory skills following working memory training. Descriptions of the assessments follow.

Raven's SPM (Raven, 1992)

Raven's SPM is a widely used assessment of non-verbal reasoning and has a test-rest reliability of .8 and over for intervals between one month and one year.

The CTOPP (Wagner et al., 1999)

The CTOPP was used as a measure of phonological processing. No parallel forms are available for this edition, and the same subtests were administered on each testing occasion.

The CTOPP was standardised on a sample of 1656 individuals in the USA, and is reported to have high internal consistency, greater than .8 for all composite items, and test-retest reliability is reported as .9 for Phonological Awareness, .8 for Phonological Memory and between .8 and .9 for Rapid Naming. The test-retest administrations were conducted two weeks apart, with no significant practice effects emerging.

The TOWRE (Torgesen et al., 1999)

The TOWRE was used as a measure of single word and non-word reading. For both sub-tests children are required to read aloud as many words as they can during a 45 second period, therefore the assessment measures speed and efficiency of lexical access and decoding. Form A was used for the pre-test and six month post-test and Form B was used for the immediate post-test. The TOWRE is reported to be reliable, with test-retest correlations after a two week period reported to be over .9.

The AWMA (Alloway, 2007)

As noted earlier, the AWMA had been used in previous studies examining the effects of working memory training or investigating links between working memory and academic success, and with children in the age range of those in the present study (Alloway et al. 2009; Dunning et al. 2013; Holmes et al. 2009) therefore seemed to be suitable for this study. A large scale study (Alloway et al., 2008), involving data from 102 children with poor working memory, selected from a data pool of more than three thousand children participating in earlier studies, found that, according to AWMA sub-tests, working memory scores were stable over the course of a school year. It was also found that the digit span sub-test correctly identified 91% of the children with poor working memory from a sub-set of 28 children, whose AWMA scores were compared with their performance on the WISC-IV Working Memory Index (Wechsler, 2004).

The version of the AWMA used in this study was standardised on a total of 746 children aged between four and eleven years. The test is reported to have good internal validity, and correlations between subtests in each domain suggest that each is a good measure of the targeted memory component. Test reliability was determined by retesting a group of 128 people drawn from the full age range for which the test is standardised, four weeks after an initial test. Scores at both times were very similar, with most correlations being .8 or better. Therefore the AWMA appeared to be fit for the purposes of this study, where it was being used to identify differences in working memory between groups, and to look for possible changes in working memory over the course of a school year.

The short form of the AWMA was used, which comprises four sub-tests: digit span is the measure of Verbal Short Term Memory; sentence recall of Verbal Working Memory; dot sequence of Visuo-spatial Short Term Memory, and spatial recall of Visuo-spatial Working Memory. Digit span requires repetition of digit strings of increasing length. Sentence recall requires increasing numbers of short sentences to be identified as true or false, for example, *bananas play music (false)*, followed by recall in sequence of the last words of each sentence. Dot sequence requires recall of the position of a sequence of dots on a grid. Spatial recall requires increasing numbers of sequentially presented pairs of shapes to be identified as reflections or rotations of each other, before recalling the positions of a dot sequence.

All sub-tests are presented on the computer and each contains a spoken introduction and practice trials. Scores for each sub-test are automatically calculated by the programme, minimising potential for administrative error. Test-retest reliability is reported as .83 for dot recall, .79 for spatial recall, .89 for digit recall and .88 for sentence recall.

Pupil Attitudes to Self and School Rating Scale (PASS, W3 Insights, 2011)

The PASS is a 50-item rating scale that has been designed to provide information about “the learning climate of a school as perceived by the pupils,” (W 3 Insights, 2011, p.8) and children’s perceptions of themselves as learners based around the following nine factors:

1. Feelings About School – this measures general well-being, safety and comfort, including feelings of connectedness within the school community
2. Perceived Learning Capability - this indicates how children feel about their learning capabilities, including how much autonomy they feel they have
3. Self-Regard - this illustrates how children’s learning experiences impact on their wider self-concept, including positive and negative feelings, and whether or not they feel that they can learn, given the right circumstances
4. Preparedness for Learning – this indicates how children view their metacognitive learning skills and behaviour and attitudes to learning
5. Attitudes to Teachers – this provides information on pupils’ perceptions of relationships with their teachers and level of social integration
6. General Work Ethic – this is a more general motivational measure and includes feelings about work, including levels of anxiety, aspirations and personal growth
7. Confidence in Learning – how children approach new and difficult tasks, including perseverance, or learned helplessness, is indicated by scores for this factor

8. Attitudes to Attendance – responses for this factor indicate how children feel about being at school, including the extent to which they would rather be elsewhere, and how they cope with school structure and routines
9. Response to Curriculum – this shows whether or not the children feel that the work they are given matches their current skills and knowledge

The instrument was standardised on 14,835 Year 3 pupils, 16,272 Year 4 pupils, 16,933 year 5 pupils and 17,009 year 6 pupils. Confidence intervals for any particular score are small, ranging from 0.43 to 1.06 of a percentile at the 99% confidence level for years 3 to 6. This means that it is possible to be 99% confident that scores are accurate to about one percentile point for those year groups.

For the present study children completed the survey online at computer terminals. If able to do so, they typed in their own personal data and then began the survey, which took about ten minutes. The reading demands of the survey are appropriate for children in Key Stage 2 but I was on hand to help children with reading if required. The survey began with a set of instructions, which were explained to the group as a whole using an electronic whiteboard.

When the children had completed the survey it was uploaded for audit. Results were sent to the school in the form of files with responses for each of the nine factors in the form of percentile scores for each child. The survey appeared to be well suited for the purposes of this study as several factors, contributing to a sense of identity as a learner, could be examined separately.

It was expected that Factor 1, Feelings about School, and Factor 8, Attitudes to Attendance, would provide general information about children's identifications within the group (Hall, 2000; Pollard, 2007), how comfortable they felt within the group, which might include the extent to which they desired the prevailing group attributes and felt that they were able to meet them. The extent to which they would rather be elsewhere rather than at school would provide information on children's happiness at school, or otherwise. Factor 2, Perceived Learning Capability, might provide information on whether or not children's metacognitive understanding relating to the tools they have for learning change after working memory training, and scores for Factor 9, Response to the Curriculum might reveal whether children feel that any improvements following working memory training are useful in approaching their work in class. Correlations were explored between the factors from PASS and the other measures described above before and six months after the working memory intervention, when changes in emotions and feelings of well-being might be expected.

Interviews

At the start of the study, semi-structured interviews were used to explore thoughts and feelings about barriers to learning for the child participants. Thematic analysis was used to identify topics and themes which the children considered to be important, which were also relevant to the research questions (Braun & Clark, 2006). Identified patterns in responses were condensed into a thematic map, from which underlying ideas were extracted.

Conducting research interviews can be problematic, as conflicts can arise between the desire to give the respondent sufficient freedom to say what they mean, and the necessity of keeping the conversation relevant to the research questions. Unstructured interviews may provide a rich source of data, but often take the research in different directions. Structured interviews run the risk of becoming question and answer sessions which could have been replaced by a questionnaire. Interviews with children can be difficult when the interviewer is also the child's current or former teacher in view of the power relationship in force, when telling the truth might appear risky for the child.

A schedule of interview prompts used in this study before and after working memory training is included in Appendix B. In order to limit the children's feelings of emotional exposure, children were asked to complete a computer-based PASS survey. PASS results were subsequently used as a prompt for conversations with the children about their feelings about school after working memory training. PASS results were not shared with the children, but where there were significant changes in scores before and after training, indirect reference was made to elicit an explanation, for example, Brad was asked about the change in his Attitudes to Teachers score as follows:

> *In September you seemed to be happy with most things in your class – has anything changed since then?*

This prompt allowed him to decide whether or not to disclose his feelings, without leading him towards a specific topic.

Auditory discrimination

It was not possible to arrange full hearing tests for the participants and any information about children's past hearing levels, based on parental reports, was sketchy as parents had not kept records. It was considered important to carry out an assessment of auditory discrimination in order to make sure that the hearing levels of the OME group were not impaired at the time of the study, and might therefore have affected the assessments of memory and phonological processing.

The children in both groups were tested individually during the summer term of 2013 using the Morgan-Barry Auditory Discrimination and Attention Test (Morgan-Barry, 1988). At this time, the four OME group children in Year 6 at the start of the study were not available. Twelve children in the OME group and twelve in the comparison group were tested. The Morgan-Barry test requires children on each trial to point to one of two pictures as it is named by the tester. The pairs of words differ by initial or final phoneme. In this way, the test assesses for accurate discrimination of words differing in single phonetic features (voice, place or manner) while memory demands are reduced. Test-retest reliability is reported at .9.

Procedure for pre-and post-training assessments

For the pre-training (Time 1) assessments, the CTOPP and TOWRE tests were administered first, then the AWMA, on separate occasions. The CTOPP took approximately twenty minutes to administer, the TOWRE five minutes, and the AWMA twenty minutes to half an hour. The post-training (Time 2) assessments and delayed follow-up (Time 3) assessments took approximately one hour each. Children were assessed individually in a quiet area at school. The same method of administration was followed for all participants on each occasion. The PASS survey was group administered at Time 1 and Time 3, and required approximately fifteen to twenty minutes. The semi-structured interviews were conducted after the other assessments at Time 1 and 3, and added another ten or fifteen minutes to each session.

The Time 1 assessments were carried out over a four week period in September, at the beginning of term. Time 2 immediate post-tests were conducted in December and January, but this period included the two week Christmas break. Time 3 delayed post-training tests were conducted six months later, between May and July 2012.

Working memory training intervention

A computer-based training programme, Cogmed, (Klingberg et al., 2002; Psychcorp, 2011) was used for the intervention. Children's participated in computer based memory training for 30 to 45 minutes each weekday for six weeks. The RM version, for children aged seven and over, was used. Each training session consists of eight activities, four focused on aspects of visual memory and four on verbal memory. Each activity comprises several trials, which adapt to performance. If three trials at one level are correct, difficulty increases, while three missed trials cause the next trial to drop a level. Children worked through the programme at their own pace. Sessions not completed on a training day were saved and continued on the next occasion, while children who completed a full session with time to spare were able to continue to the next set. According to Cogmed training instructions, twenty training sessions counts as completed training, although 25 to 30 sessions may be completed. Some children completed the basic 20 sessions while others finished all 25. Differences in the number of training sessions has not been included in the analysis section, as according to Alloway's findings (2013), the number of sessions, slightly more or less than 20, made no difference to outcomes.

The training took place mainly at school, either before lessons, during assembly time, or during the long lunch break, depending on the needs and wishes of individual parents and children, with some sessions supervised by parents and completed at home. School sessions were held in the school's computer room which holds 20 flat screen computers, or in a second multi-function room with 20 laptops. No more than twelve children were working on the programme in either of the computer suites at any one time and care was taken to seat children with greater concentration issues between unused terminals. Two children, one from the OME and one from the comparison group, found working in a large group very difficult and separate arrangements were made for them to train on an individual basis. Training effects on working memory for these two children were similar to effects for other children in their groups. Children did not miss any timetabled lessons in order to take part in the memory training, but those completing the programme mainly at school missed some of their playtimes. This might have contributed to motivational issues, as a result of which five children from the comparison group dropped out of the study.

Data collection schedule

The timing of collection of pre-training, post-training and delayed assessment data for the two groups and of the delivery of the training is shown in Table 6.

Table 6: Schedule of assessment data collection and delivery of training (Time 1: pre-training, Time 2: immediate post-training, Time 3: six months delayed post-training

Date	***Data collected***
Time 1	Raven's SPM, semi-structured interviews with children, PASS, AWMA CTOPP, TOWRE , working memory training intervention (6 weeks)
Time 2	CTOPP, TOWRE, AWMA
Time 3	CTOPP ,TOWRE, PASS, AWMA repeat interviews
May 2013	Auditory Discrimination and Attention Assessment

Data analysis

Numerical data were collected in the form in which they were to be analysed, and entered into the data set as the results became available. There were no missing data. Standardised assessment scores were entered into IBM SPSS Statistics 20 for analysis.

This study contained fixed design features requiring confirmatory analysis to determine whether or not my findings were as expected (Robson, 2002). Descriptive statistics were examined for measures of central tendency and variability. Initially, group results were compared to determine whether statistically significant differences existed on measures of working memory, phonological awareness, single word and non-word reading, school-based English and maths and PASS survey factors. The magnitude of any differences was explored using

Cohen's *d*. Correlational analyses were also conducted to look for relationships between PASS factors and working memory assessment scores. Due to the small sample size in this study, correlations were not statistically significant unless at least moderate, around .6 and above. Therefore, "only robust effects are going to be picked up." (Robson, 2002, p. 402).

Ethics

All data collected for the purposes of this study remained confidential. All paper-based records created for this study were retained securely in a locked cupboard with restricted access, while computer records were password protected. Pseudonyms have been used for the school and children. Interviews were conducted sensitively and in privacy and parents were offered the opportunity to be debriefed as to the main findings of the study on completion.

No inducements were offered to participants, nor were any extravagant claims made as to the potential benefits of the working memory training in order to persuade parents to participate. After consideration of the research based evidence (Holmes, et al., 2009) and scrutiny of information provided by PsychCorp (2011) a decision was made to purchase Cogmed computerised working memory training software as part of the school's enrichment programme, currently focused on thinking skills. The training was offered to all children from year 1 upward during the course of the academic year 2011-12, with preference given to those already identified with working memory limitations.

Parents were provided with sufficient details about the training and interview structure during the personal invitation or in the form of an information letter, in order to enable them to make an informed decision about participation. A copy of the letter is attached in Appendix C. Article 12 of the Convention on the Rights of the Child, 1989, makes consideration of the children's rights equally important. While teachers and parents may feel that participation in the memory training would benefit a child, it may be that the child did not wish to participate, for various reasons, and as mentioned in the participants section, one child declined to participate and others dropped out during training. Child consent was obtained by personal invitation to attend a computer club. The children were told that the computer programme might help them with their learning, and that assessments would be required before and after training to monitor the effects. A reward schedule was set up to assist with motivation. For each new high score on the programme, children collected a raffle ticket, which could be exchanged at a later date for a small reward such as an eraser or a pencil.

I did not anticipate that the child participants would suffer any emotional discomfort or negative feelings as a result of the study and I expected that they would enjoy the training, look forward to the sessions, and, should the intervention be successful, reap benefits as their memory skills improved. The PASS survey was presented as a consultation, for children to let me know how they felt about aspects of their learning, and as consultation is an established part of the school's continued self-evaluation process, the children are used to taking part in this.

In my experience, parents are often upset when talking about their child's potential learning difficulties and fear the worst. Offering parents the opportunity to discuss their child's difficulties and have their questions answered forms part of my everyday role at school. Parents were assured that the level of service provided to children and parents in execution of this role would not be affected if they decided not to participate, or not to allow their children's data to be included in the study report.

Teachers at the school were given the opportunity to participate in the programme, which should have improved their understanding of the characteristics and behaviours associated with poor working memory and may have effected changes in classroom management and teaching strategies. Three teachers volunteered to attend training during 2011-12. It was part of my role as a member of the school's Leadership Team at that time, to build capacity in colleagues and encourage them to move their teaching forward. Introduction of the intervention helped to fulfil that aspect of my role.

Drawbacks to insider research of this kind include difficulty in setting and maintaining research boundaries as interests shift while pursuing solutions to real world problems, reconciling the demands of the research study with unremitted everyday school responsibilities, variations to research sample size as children leave the school before completion of the study and issues of power and influence. Therefore care was taken not to place heavy demands on colleagues' time and patience.

Chapter 4: Results

Introduction

This chapter begins by presenting the OME group and comparison group scores, for memory processes assessed by the AWMA, before training, immediately after training, and again six months later. This is followed by the group results at the same timepoints for phonological processing from the CTOPP and reading from the TOWRE. Then the results from the school based assessments Progress in Maths and Progress in English are presented, before training, and in the following summer term. Following this are the results from the learner identity PASS survey, and then the qualitative results from the interviews. The group differences were analysed using ANOVAs and t-tests.

A potential problem for data analysis is that it is possible to find a significant difference when there is really no difference between the groups, a Type 1 error, and the possibility of making such an error increases with the number of comparisons conducted (Pallant, 2007). Attempts to minimise the possibility of a Type 1 error, such as changing the alpha level, might increase the possibility of making a Type 2 error, which means that differences between the groups could be overlooked. Additionally, Type 2 errors are more likely in studies with small sample sizes (Stevens, 1996, in Pallant, 2007).

The present study has small sample sizes and makes several comparisons, both between the OME group and comparison group, and repeated measures comparisons looking at changes within both groups over time. To minimise the possibility of committing a Type 1 error, mixed between-within subjects ANOVA were selected to combine these planned comparisons where appropriate, and significance of the overall F ratio was calculated before additional tests were performed.

Correlation analyses are reported for the PASS survey scores and other variables to examine relationships between working memory capacities and children's feelings about themselves as learners and attitudes to learning. The data were analysed using IBM Statistics 20 software. Significant differences are reported at $p<.05$ or better. Individual children's scores are reported in Appendix D.

Research question 1: Are working memory capacities of children in this study with parental report of early onset OME different from those of their typically developing peers?

The scores for the OME and comparison group in the AWMA, presented in the Participants section (Table 4), addresses the first research question. The OME group were found to have significantly lower scores in all four measures of the AWMA.

Research question 2: What are the effects of working memory training on working memory, phonological abilities, reading skills and other academic achievements?

In order to address this research question, the group results on measures of memory, phonological processing and reading before (Time 1), immediately after (Time 2) and six months after training (Time 3) are reported. The results of the school-based assessments (Progress in English and Progress in Maths) from the summer term before the training and the summer term following training are also presented.

AWMA results

A summary of the standardised scores in the AWMA for verbal short-term memory and working memory, and visuo-spatial short-term memory and working memory for the OME group and comparison group at the three time points is presented in Table 7.

Table 7: Mean scores in the AWMA for the OME and comparison group at Time 1, 2 and 3 (standard deviations are in parenthesis)

	Time 1		*Time 2*		*Time 3*	
	OME	*Comparison Group*	*OME*	*Comparison Group*	*OME*	*Comparison Group*
Verbal short term memory	98.43 (16.05)	111.99 (12.89)	110.83 (14.00)	115.75 (11.51)	115.56 (19.72)	118.17 (13.38)
Verbal working memory	94.56 (11.62)	108.41 (15.11)	108.64 (11.75)	116.50 (12.32)	111.19 (13.61)	118.83 (13.00)
Visuo-spatial short term memory	106.94 (15.62)	120.75 (14.13)	124.06 (7.92)	133.58 (9.69)	128.44 (12.85)	134.25 (11.27)
Visuo-spatial working memory	102.63 (13.25)	115.25 (9.55)	113.49 (13.14)	125.33 (8.66)	122.00 (13.82)	123.75 (9.30)

The data were analysed using a series of mixed ANOVAs, where the between subjects factor was Group (OME vs. comparison group) and the within-subjects factor was timepoint (Time 1 vs. Time 2 vs. Time 3). The first analysis involved the data for verbal short term memory. A plot of the data is given in Figure 5.

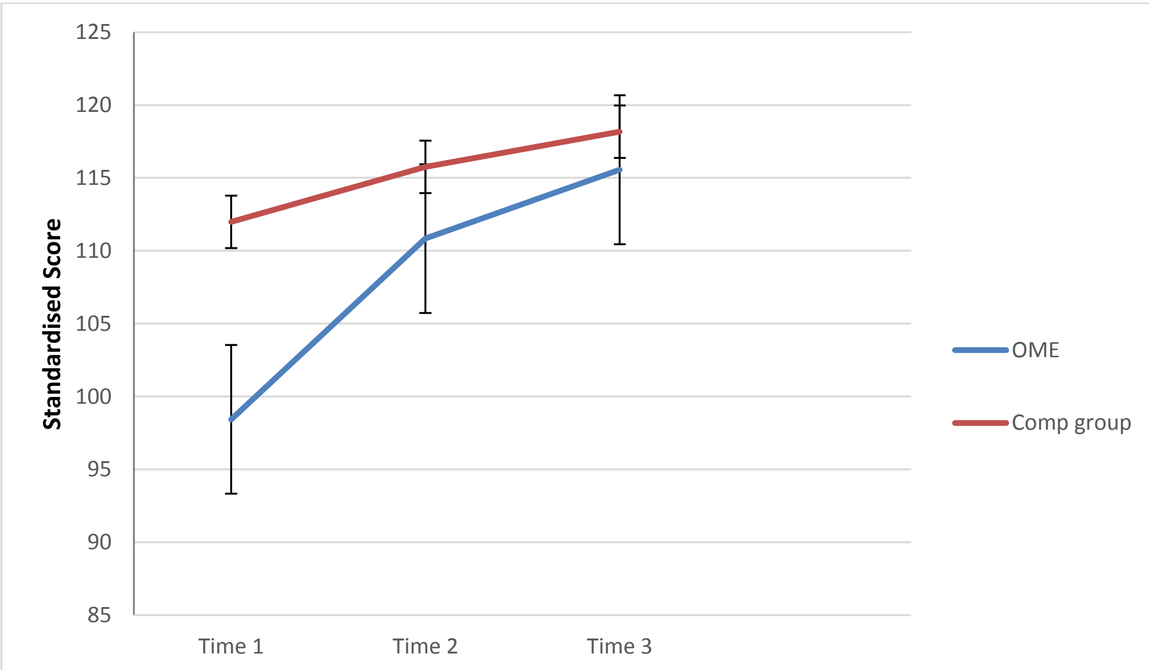

Figure 5: Plot of AWMA verbal STM scores for the two groups at the three timepoints

The main effect of group was not significant, $F(1,26)=1.9969$, $p=.172$, eta=.070. The main effect of time was significant, $F(2,25)=12.916$, $p<.001$, eta=.508, and the interaction of time x group was marginally significant, $F(2,25)=3.360$, $p=.051$, eta=.212. Exploration of the interaction with independent t-tests revealed that the effect of group was significant at Time 1, $t(26)=2.400$, $p=.024$, but not at Time 2, $t(26)=.990$, $p=.331$, or Time 3, $t(26)=.394$, $p=.697$.

The same analysis of the data for verbal working memory (see Figure 6) revealed a significant main effect of group *F*(1,26)=5.857, p=.023, eta=.184, with higher scores for the comparison group (as in all the analyses reported below, except where stated). The main effect of time was also significant *F*(1,25)=16.376, p<.001, eta=.567, but the interaction of time x group was not *F*(1,25)=0.979, p=.390, eta=.073. Although the interaction was not significant it was considered important to test for group differences at the different timepoints, given the a priori predictions (that the intervention would reduce group differences in memory processes). T-tests revealed that, as for verbal STM, the effect of group was significant at Time 1, t(26)=2.746, p=.011, but not at Time 2, t(26)=1.715, p=.098 or Time 3, t(26)=1.499, p=.146.

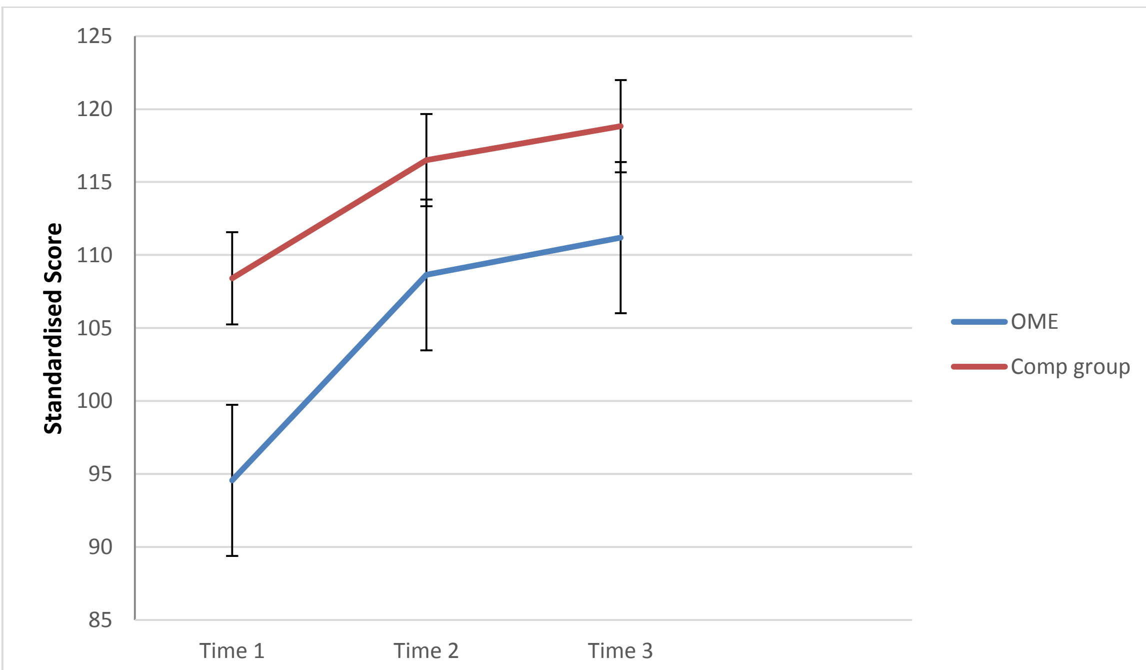

Figure 6: Plot of AWMA verbal working memory scores for the two groups at the three timepoints

The data for visuo-spatial STM (see Figure 7) revealed a significant effect of group, *F*(1,26)=6.161, p=.020, eta=.192. The main effect of time was also significant *F*(1,25)=33.196, p<.001, eta=.726, but the interaction of time x group was not, *F*(1,25)=1.820, p=.183, eta=.127. There was a significant effect of group at Time 1, t(26)=2.445, p=.022. In this analysis there was also a significant effect of group at Time 2, t(26)=2.864, p=.008, but not at Time 3, t(26)=1.247, p=.223.

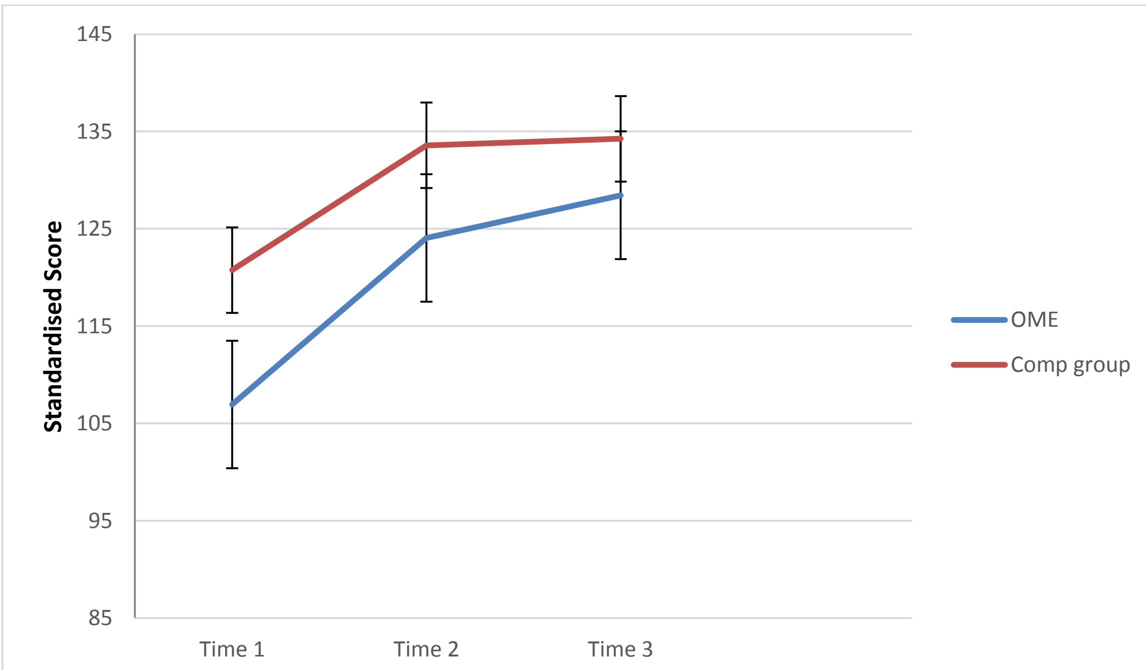

Figure 7: Plot of AWMA visuo-spatial STM scores for the two groups at the three timepoints

Analysis of the results for visuo-spatial working memory (see Figure 8) revealed a significant main effect of group, $F(1,26)=5.397$, $p=.028$, eta=.172. The main effect of time was also significant, $F(1,25)=19.823$, $p<.001$, eta=.613, as was the interaction of time x group, $F(1,25)=3.540$, $p=.044$, eta=.221. Exploration of the interaction revealed that the effect of group was significant at Time 1, $t(26)=2.795$, $p=.010$, and at Time 2, $t(26)=2.707$, $p=.012$, but not at Time 3, $t(26)=.378$, $p=.708$.

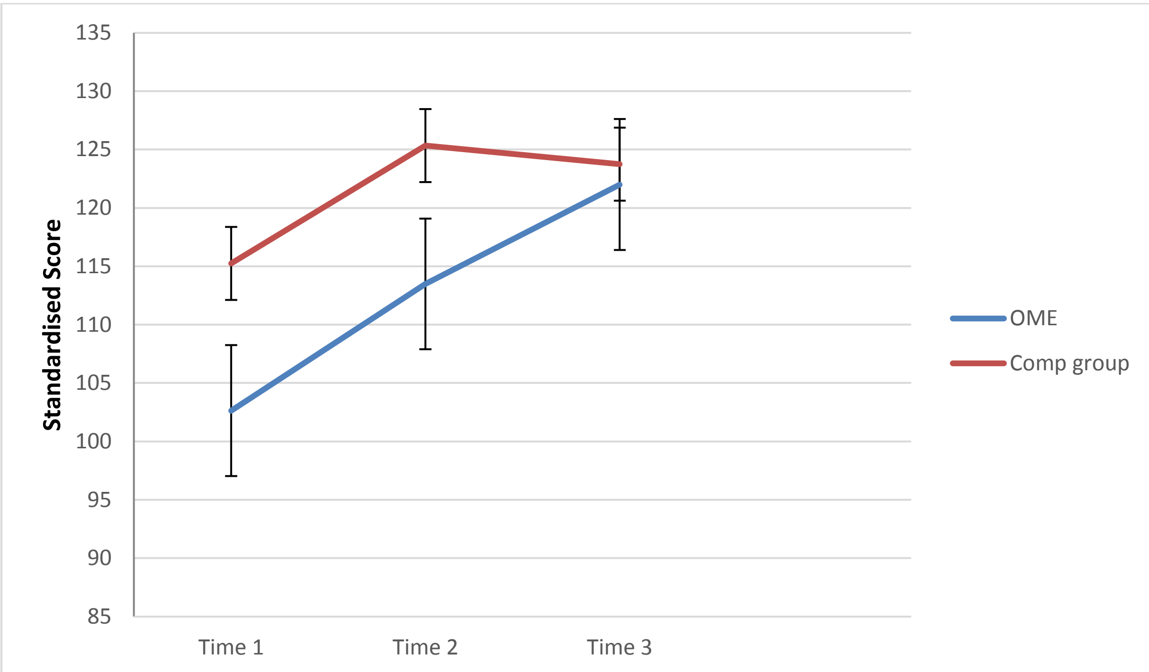

Figure 8: Plot of AWMA visuo-spatial working memory scores for the two groups at the three timepoints

Differences in AWMA performance within the groups across Time 1, Time 2 and Time 3

Analyses were conducted to examine the extent of any changes in performance of the groups for each measure in the AWMA after training. Repeated measures t-tests were used for these analyses. T-test values for the significant differences are given in Table 8. Inspection of Table 8 reveals that the Time 1 – Time 2 difference was significant for the OME group for all four AWMA measures, but only for the visuo-spatial measures for the comparison group. The Time 2 – Time 3 difference was significant for the visuo-spatial measures for the OME group.

Table 8: Significant differences (t-test values) in AWMA scores at Time 1 – Time 2 and at Time 2 – Time 3 for the OME and comparison groups

Test	***OME***	***Comparison Group***	***OME***	***Comparison Group***
	T1 – T2	**T1 – T2**	**T2 – T3**	**T2 – T3**
Verbal short term memory	4.685***	NS	NS	NS
Verbal working memory	5.293***	NS	NS	NS
Visuo-spatial short term memory	5.387***	3.479**	2.138*	NS
Visuo-spatial working memory	3.999***	3.247**	3.214**	NS

Note: *p<.05, **p<.01, ***p<.001

Summary of results for AWMA

The results showed the OME group had significantly poorer scores than the comparison group at Time 1 in all four aspects of memory assessed by the AWMA. Analyses of the verbal STM and verbal WM scores revealed that the OME group had made significant improvement in both measures after training, and the differences between the two groups were no longer significant. The significant interaction effect for verbal STM indicated that the intervention was more effective for children in the OME group than the comparison group. For verbal WM, although the interaction effect was not significant, suggesting that the intervention was equally effective for the OME group and comparison group, differences were not significant at Time 2 and the improvement was maintained, since at Time 3, the group difference was again not significant.

For visuo-spatial STM and WM, both the OME and comparison group made significant improvement in scores following training, and the effect of group was still significant at Time 2. The non-significant interaction effect for visuo-spatial STM suggested that the intervention was equally effective for the OME and comparison group, but the overall continued improvement of the OME group diminished the difference between these groups by Time 3, when the scores of the OME group were no longer significantly lower than those of the comparison group. The results suggest a ‘sleeper effect’ for the OME group – while training appeared to result in improvement in both groups, there was further improvement for the OME group after training ceased.

We can be reasonably confident that the improvement in scores observed in the two groups was as a result of the training since results for the no-training group (see Table 5) show no significant change in scores over an equivalent time period on any of the measures. This indicates that the improvement observed for the OME and comparison groups was due to the intervention and not test-retest effects. As found in the studies of Loosli et al. (2012) and Dahlin (2011), the largest gains in AWMA scores were found for the children (in the OME group) with the poorest pre-training performance.

CTOPP results

A summary of the standardised scores in the CTOPP for phonological awareness, phonological memory and rapid naming for the OME group and the comparison group at the three time points is presented in Table 9.

Table 9: Mean CTOPP scores for the OME and comparison group at the three timepoints (standard deviations are in parentheses)

Test	***Time 1***		***Time 2***		***Time 3***	
	OME	***Comparison Group***	***OME***	***Comparison Group***	***OME***	***Comparison Group***
Phonological Awareness	103.94 (9.50)	113.25 (12.30)	116.13 (12.14)	125.50 (14.58)	123.06 (9.78)	128.75 (5.79)
Phonological Memory	95.69 (10.10)	104.00 (11.18)	103.00 (11.70)	110.50 (10.89)	103.00 (11.80)	113.75 (10.51)
Rapid naming	103.56 (10.63)	104.00 (8.89)	106.38 (8.04)	103.25 (11.04)	104.50 (9.10)	110.50 (10.97)

Note: *p<.05, **p<.01, ***p<001

As for the AWMA results, the data were analysed using a series of mixed ANOVAs, were the between subjects factor was Group (OME vs comparison group) and the within-subjects factor was timepoint (Time 1 vs Time 2 vs Time 3). The first analysis involved the data for phonological awareness. A plot of the data is given in Figure 9.

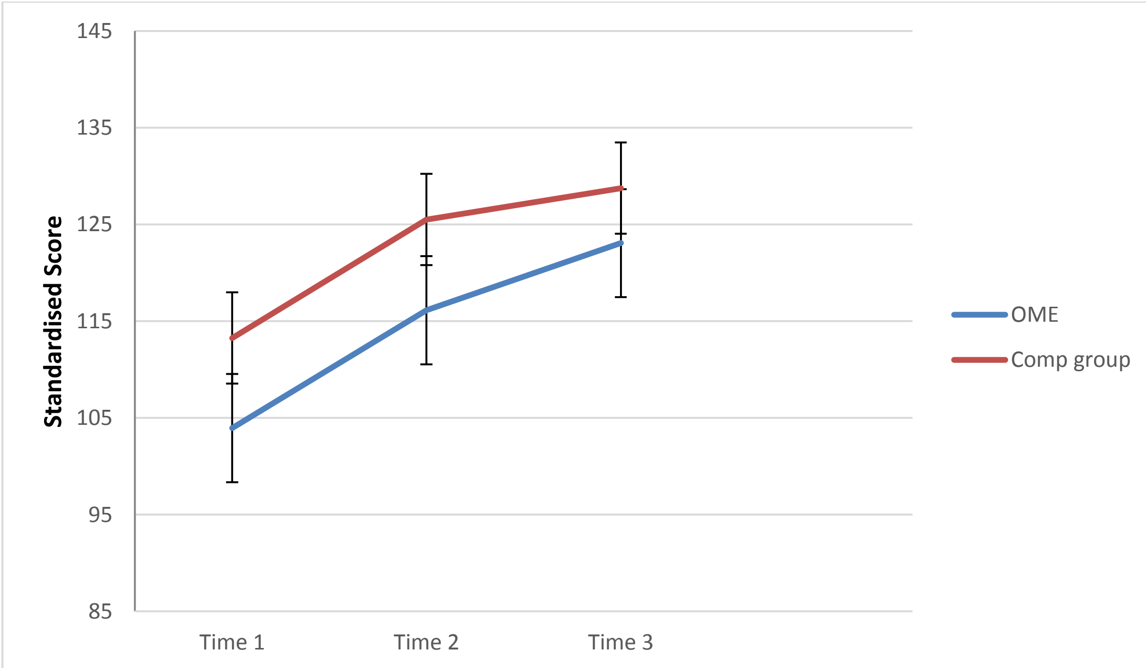

Figure 9: Plot of mean CTOPP phonological awareness scores for the two groups at the three timepoints

The main effect of group was significant, $F(1,26)=5.696$, $p=.025$, eta=.180. The effect of time was significant, $F(2,25)=46.314$, $p<.001$, eta=.787, and the interaction of time x group was not significant, $F<1$.

Analysis of the results for phonological memory (see Figure 10) revealed a significant effect of group, *F*(1,26)=5.391, p=.028, eta=.172. The effect of time was significant, *F*(2,25)=19.229, p<.001, eta=.606. The interaction of time x group was not significant, *F*<1.

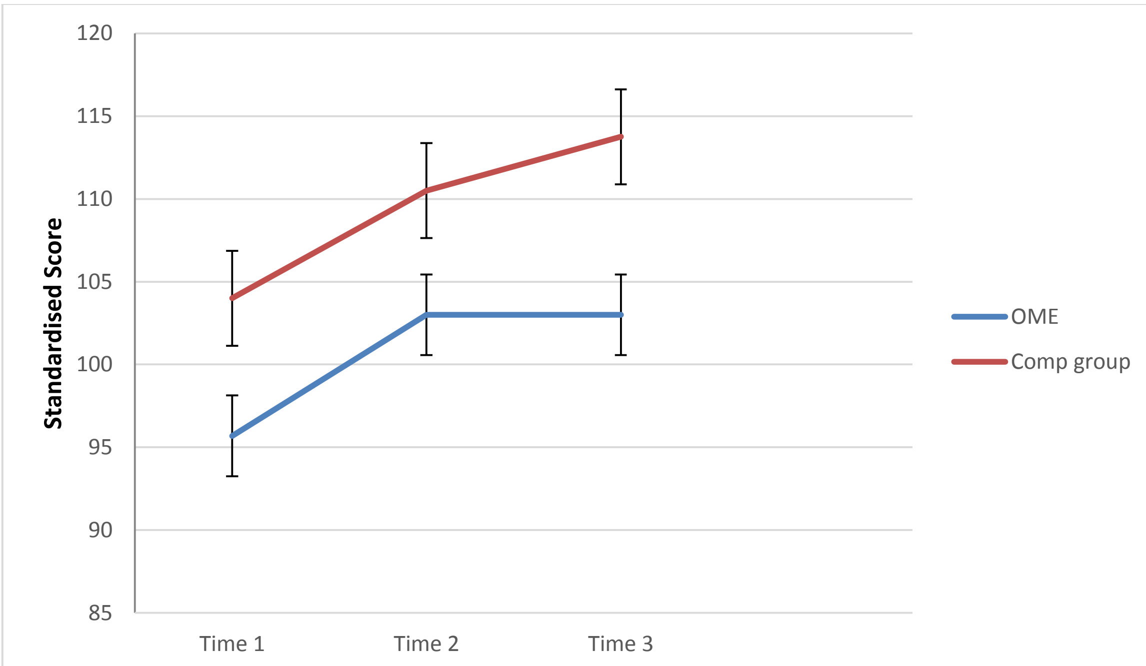

Figure 10: Plot of mean CTOPP phonological memory scores for the two groups at the three timepoints

Analysis of the results for rapid naming (see Figure 11) revealed a non-significant effect of group, *F*<1, and of time, *F*(2,25)=2.469, p=.105, eta=.165. The interaction of time x group was significant, *F*(2,25)=4.282, p=.025, eta=.255. Exploration of the interaction revealed that the effect of group was not significant at Time 1, t(26)=.115, p=.909, at Time 2, t(26)=.868, p=.393, or Time 3, t(26)=1.576, p=.127. Inspection of the figure suggests that the interaction was due to the fact that the comparison group showed significant improvement in scores between Time 2 and Time 3 (see next section).

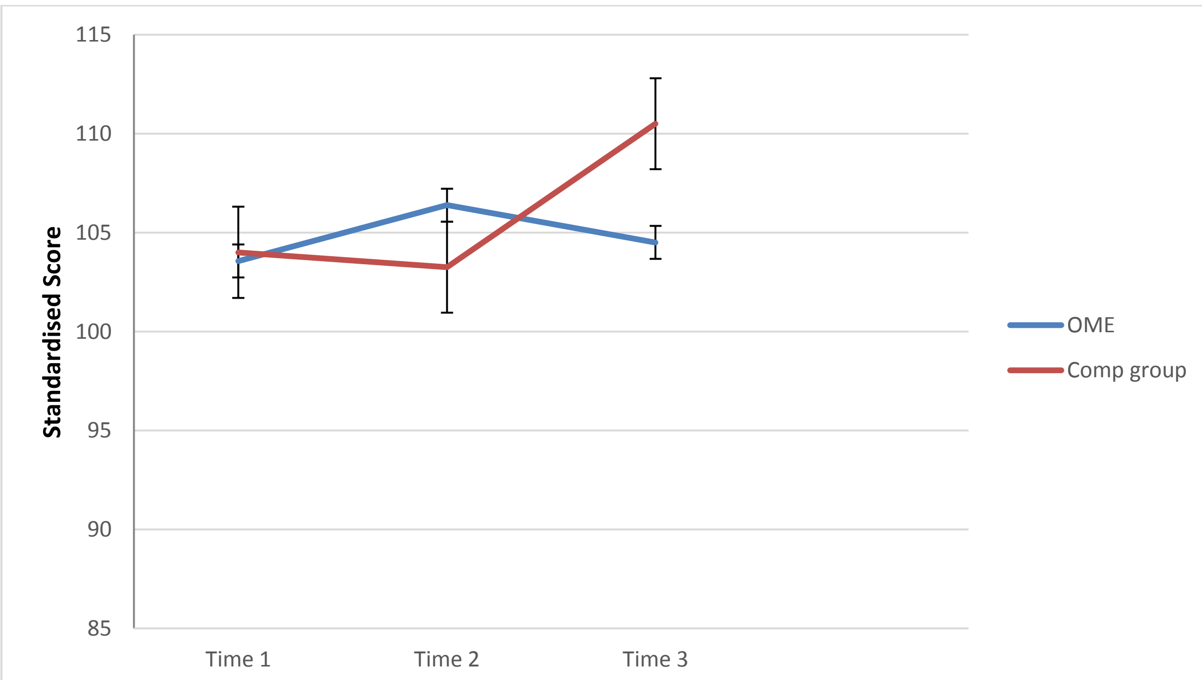

Figure 11: Plot of mean CTOPP rapid naming scores for the two groups at the three timepoints

Difference in CTOPP performance within the groups across Time 1, Time 2 and Time 3

Analyses were conducted to examine the extent of change in performance of the groups for each measure in the CTOPP after training. T-test values for significant differences are given in Table 10. Inspection of Table 10 reveals that the Time 1 – Time 2 difference was significant for the OME group for phonological awareness and phonological memory, and this was also the case for the comparison group. The Time 2-Time 3 difference was significant for phonological awareness for the OME group and rapid naming for the comparison group.

Table 10: Significant differences (t-test values) in CTOPP scores for the two groups at all three time points

Test	***OME***	***Comparison Group***	***OME***	***Comparison Group***
	T1 – T2	**T1 – T2**	**T2 – T3**	**T2 – T3**
Phonological Awareness	4.418***	5.786***	3.056**	NS
Phonological Memory	4.650***	2.572*	NS	NS
Rapid Naming	NS	NS	NS	2.978*

Note: *p<.05, **p<.01, ***p<.001

Summary of results for CTOPP

The results showed that the OME group had significantly lower scores than the comparison group for both phonological awareness and phonological memory. Both groups made gains in the two measures, the comparison group to a lesser extent than the OME group in phonological memory. The OME group showed continued gain from Time 2 – Time 3 for phonological awareness. For rapid naming the only significant change in scores was a modest increase for the comparison group at Time 2 – Time 3.

TOWRE results

A summary of the standardised scores in the TOWRE for sight vocabulary and for non-word reading at the three timepoints is presented in Table 11.

Table 11: Mean TOWRE scores for the two groups at the three timepoints (standard deviations are in parentheses)

Test	***Time 1***		***Time 2***		***Time 3***	
	OME	***Comparison Group***	***OME***	***Comparison Group***	***OME***	***Comparison Group***
Sight word recognition	108.56 (9.93)	112.75 (8.69)	112.75 (10.38)	115.75 (10.23)	115.13 (7.14)	118.17 (9.74)
Phonemic Decoding	101.38 (10.68)	111.83 (13.07)	109.75 (10.65)	114.75 (14.44)	109.56 (8.91)	117.17 (12.93)

The results were analysed as before, with mixed ANOVAs, where the between subjects factor was group (OME vs comparison group) and the within-subjects factor was timepoint (Time 1 vs Time 2 vs Time 3). The first analysis involved the data for sight word recognition. A plot of the data is given in Figure 12.

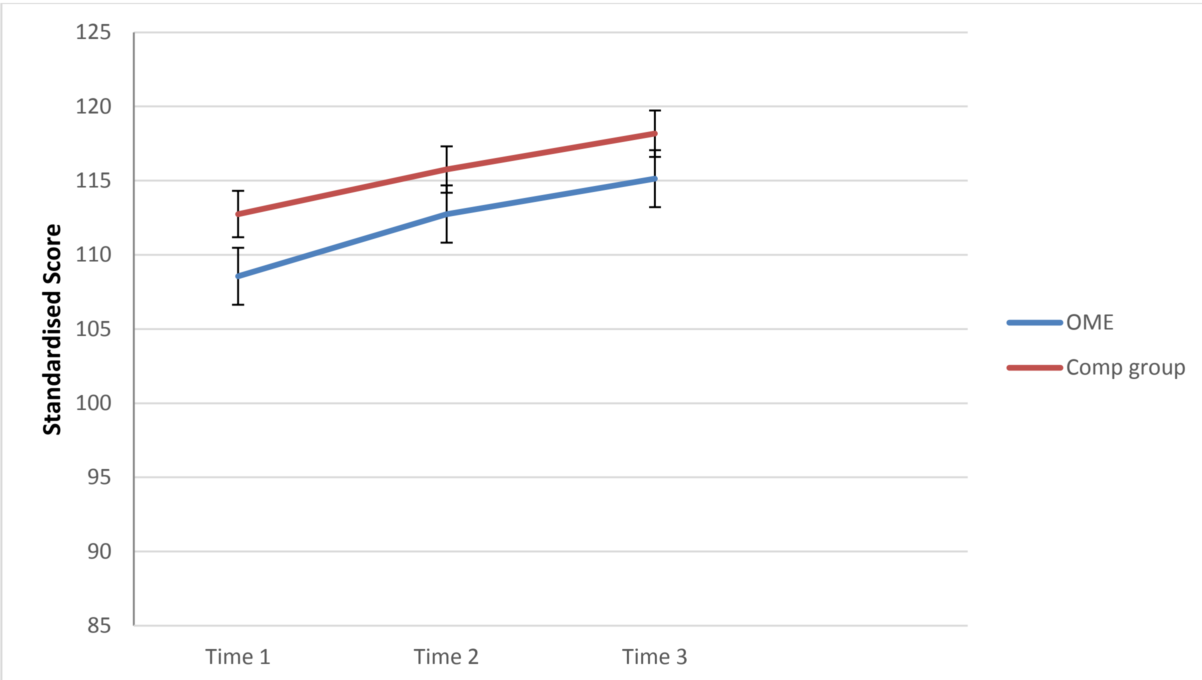

Figure 12: Plot of the mean TOWRE sight word reading scores for the two groups at the three timepoints

The effect of group was not significant, $F(1,26)=1.080$, p=.308, eta=.444, although the effect of time was significant, $F(2,25)=9.971$, p=.001, eta=.787. The interaction of time x group was not significant, $F<1$.

The results for non-word reading (see Figure 13) revealed, similarly, a non-significant effect of group, *F*(1,26)=3.681, p=.066, eta=.124. The effect of time was significant, *F*(2,25)=8.909, p=.001, eta=.416. The interaction of time x group was not significant, *F*(2,25)=1.541, p=.234, eta=.110.

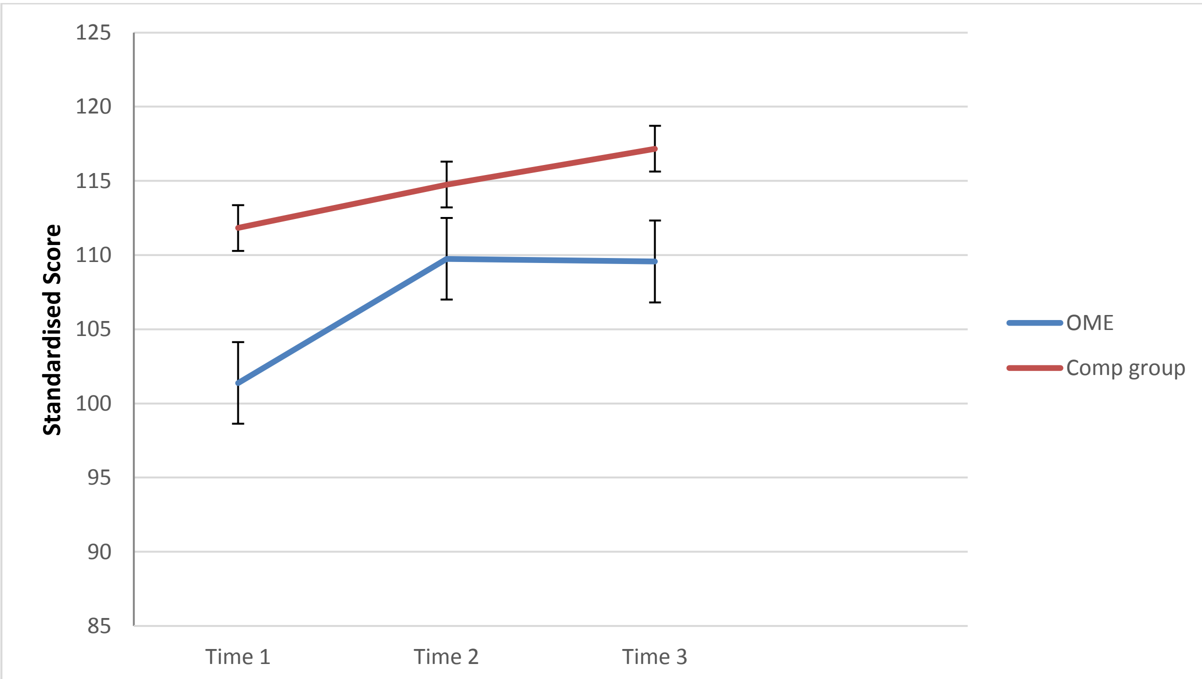

Figure 13: Plot of mean TOWRE non-word reading scores for the two groups at all three time points

Difference in TOWRE performance between the groups across Time 1, Time 2 and Time 3

Analyses examining the extent of change in performance for each measure in the TOWRE after training (t-test values for significant differences are in Table 12), revealed that the Time 1 – Time 2 difference was significant for the OME group for sight word reading and non-word reading. None of the other differences was significant.

Table 12: Significant differences (t-test values) in TOWRE scores at Time – Time 2 and Time 2 – Time 3 for the OME and comparison groups

Test	***OME T1-T2***	***Comparison Group T1-T2***	***OME T2-T3***	***Comparison Group T2-T3***
Sight word Recognition	2.191*	NS	NS	NS
Non-word reading	3.843**	NS	NS	NS

Note: *p<.05, **p<.01, ***p<.001

Summary of results for TOWRE

OME group scores were poorer than comparison group scores for sight word reading and non-word reading at all three timepoints, but only non-word reading scores were significantly poorer before training. The OME group made a small gain in sight word recognition and a substantial gain in non-word reading. Gains were not significant for the comparison group.

Progress in English and Progress in Maths results

A summary of the standardised scores in Progress in English and Progress in Maths is presented in Table 13. The two timepoints were in the summer of 2011 prior to intervention, and following intervention in the summer of 2012, at approximately the same time as the delayed post-training assessment was carried out for the AWMA, CTOPP and TOWRE.

Table 13: Mean Progress in English and Progress in Maths scores for the two groups at two timepoints (standard deviations are in parentheses)

Test	***Time 1***		***Time 2***	
	OME	***Comparison Group***	***OME***	***Comparison Group***
Progress in English	99.81 (12.51)	107.08 (6.84)	104.25 (12.76)	110.33 (9.06)
Progress in Maths	102.19 (11.75)	108.17 (10.22)	104.75 (11.64)	112.00 (10.18)

The data were analysed with mixed ANOVAs where the between-subjects factor was Group (OME vs comparison group) and the within-subjects factor was Time (Time 1 vs Time 2). The first analysis involved the data for Progress in English. A plot of the data is given in Figure 14.

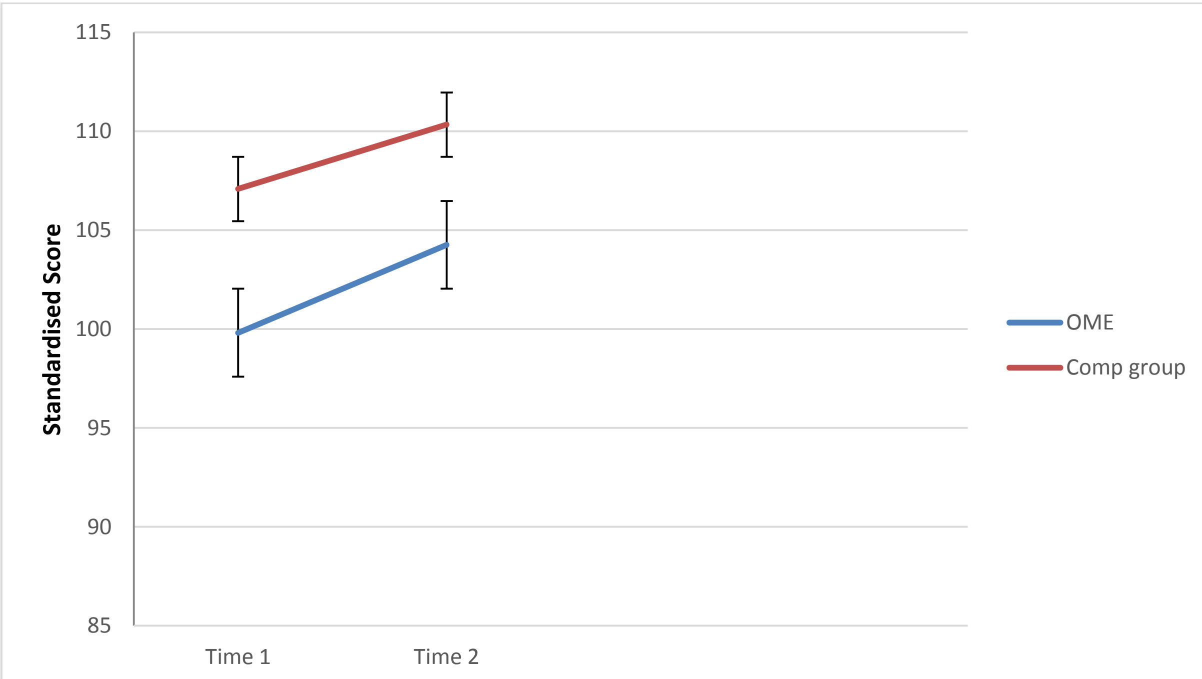

Figure 14: Plot of mean Progress in English scores for the two groups at the two timepoints

The main effect of group was not significant, $F(1,26)=2.942$, $p=.098$, eta=.102. The effect of time was significant, $F(1,26)=6.576$, $p=.016$, eta=.202. The interaction of time x group was not significant, $F<1$.

Analysis of the results for Progress in Maths (see Figure15) revealed that the effect of group was not significant, $F(1,26)=2.723$, p=.111, eta=.095. The effect of time was significant, $F(1,26)=5.493$, p=.027, eta=.174. The interaction of time x group was not significant, $F<1$.

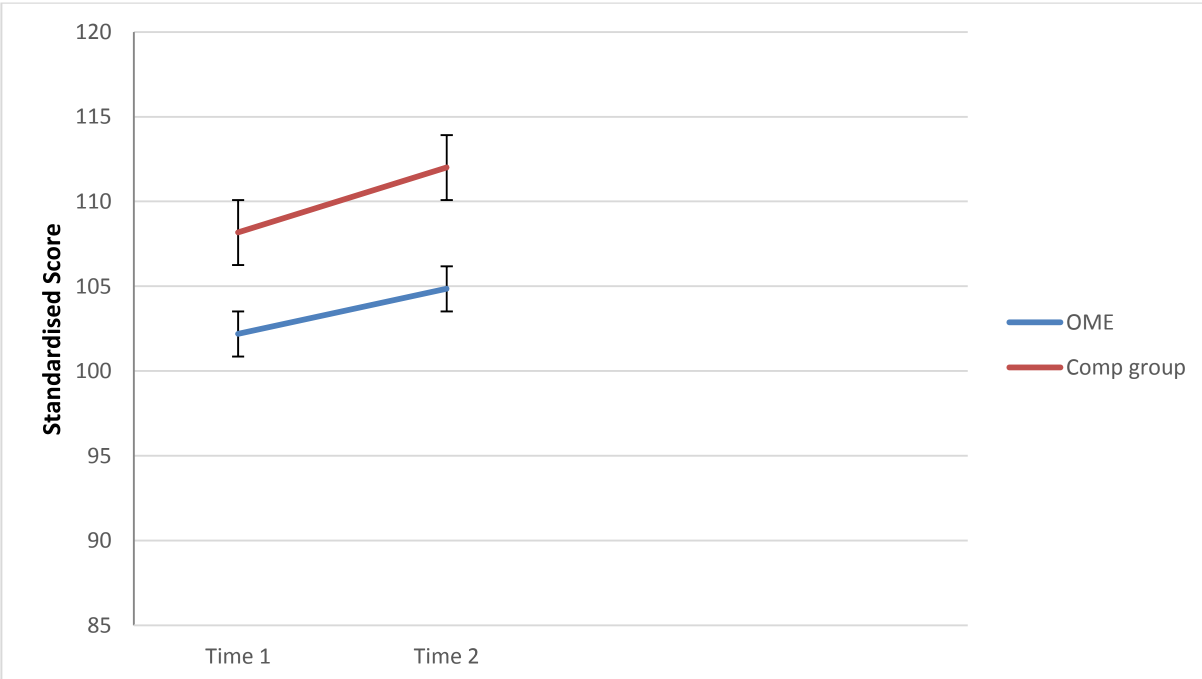

Figure 15: Plot of mean Progress in Maths scores for the two groups at the two timepoints

Differences in Progress in English and Progress in Maths within the groups for Time 1 and Time 2

Analyses examining the extent of change for each measure after training (t-test values are in Table 14), revealed that the Time 1-Time 2 difference was significant for the OME group for Progress in English. None of the other differences was significant.

Table 14: Significant differences in PiE and PiM scores (t-test values) Time 1 – Time 2 for the OME and comparison groups

Test	***OME T1-T2***	***Comparison Group T1-T2***
Progress in English	2.146*	NS
Progress in Maths	NS	NS

Note: *p<.05, **p<.01, ***p<.001

Summary of results for Progress in English and Progress in Maths

The results showed that for Progress in English and Progress in Maths, although the OME group had lower scores than the comparison group for both assessments, group differences were not significant. In the case of pre-training Progress in English, group differences appear quite large but fell short of significance. The OME group showed improvement in scores for Progress in English following the training. Gains were non-significant for the comparison group.

Research question 3: Are working memory abilities linked with children's learning identities and attitudes to learning in this study?

The measure of children's learning identities and attitudes to learning was PASS survey scores. The survey was administered at two timepoints: immediately before and six months after training. A summary of PASS ratings in the nine different factors for the OME group and comparison group at the two timepoints is presented in Table 15. In order to see whether PASS results were associated with working memory abilities, correlational analyses were carried out. These are reported next.

Table 15: Mean PASS ratings for the OME group and comparison group at the two timepoints (standard deviations are in parentheses)

Test	***Time 1***		***Time 2***		***F ratios***	***F ratios***	***F ratios***
	OME	***Comparison group***	***OME***	***Comparison group***	***Group***	***Time***	***Group X Time***
Feelings about school	55.35 (35.33)	67.53 (26.51)	50.23 (31.11)	43.47 (26.01)	<1	3.802	1.600
Perceived learning capacity	36.63 (28.03)	44.67 (20.13)	40.90 (31.44)	55.53 (22.86)	1.680	2.135	<1
Self Regard	42.89 (26.68)	40.53 (29.76)	35.25 (26.03)	58.88 (23.11)	1.771	<1	4.397*
Prepared. for learning	51.54 (26.07)	57.51 (25.42)	44.32 (22.09)	46.59 (17.11)	<1	2.905	<1
Attitudes to teachers	43.72 (31.31)	49.52 (31.46)	45.39 (25.66)	48.30 (31.24)	<1	1.877	<1
General work ethic	44.56 (27.32)	41.24 (31.70)	52.66 (27.41)	52.33 (28.10)	<1	<1	<1
Learner confidence	41.97 (28.34)	38.42 (23.22)	42.08 (28.94)	43.35 (21.00)	<1	<1	<1
Attitudes to attendance	48.78 (26.35)	53.65 (17.15)	47.35 (28.76)	49.27 (29.80)	<1	<1	<1
Response to the curriculum	53.25 (29.08)	54.11 (24.93)	43.92 (25.78)	54.26 (21.14)	<1	<1	<1

Tables 16 and 17 show correlations between AWMA subscales and PASS survey factors for the OME and comparison groups for the two timepoints.

Table 16: OME Group pre- and six month post-training correlations between AWMA and PASS factors. Pre-training correlations are below, and post-training above, the diagonal

OME (n16)	*V STM*	*V WM*	*VS STM*	*VS WM*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
AWMA V STM					.074	-.059	.355	.148	.527*	.154	.152	.277	.643**
AWMA V WM					-.461	.191	.385	.155	.209	.153	.056	.087	.379
AWMA VS STM					-.161	.011	.142	.121	.394	-.322	-.203	.203	.261
AWMA VS WM					-.540	.034	.315	.036	-.142	.147	.114	-.013	.633**
PASS													
1 Feelings about school	.154	-.246	.072	.068									
2 Perceived learning capacity	.210	-.082	.151	.101									
3 Self regard	-.031	.113	-.395	-.253									
4 Preparedness for learning	.307	-.088	-.033	.101									
5 Attitudes to teachers	.249	-.198	.059	-.117									
6 General work ethic	.105	-.005	-.320	-.253									
7 Learner confidence	.004	-.383	-.060	-.030									
8Attitudes to attendance	-.060	-.332	-.298	-.142									
9 Response to the curriculum	.233	.293	-.339	-.253									

Note: *p<.05, **p<.01, ***p<.001

Table 17. Comparison Group pre- and six month post training correlations between AWMA and PASS factors. Pre-training correlations below and post-training above the diagonal

OM- Group (n12)	***V STM***	***V WM***	***VS STM***	***VS WM***	***PASS 1***	***PASS 2***	***PASS 3***	***PASS 4***	***PASS 5***	***PASS 6***	***PASS 7***	***PASS 8***	***PASS 9***
AWMA V STM					-.069	-.231	-.204	-.190	-.200	-.007	-.305	-.145	.084
AWMA V WM					-.476	-.090	-.310	-.679	.154	.007	.115	-.467	-.166
AWMA VS STM					-.082	.108	.231	.233	.349	-.121	-.252	.033	-.039
AWMA VS WM					-.071	-.093	.007	.332	-.432	-.703	.163	.001	.063
PASS													
1 Feelings about school	.016	-.448	.098	.046									
2 Perceived learning capacity	.282	.487	.466	.598*									
3 Self-regard	.087	-.036	.635*	.132									
4 Preparedness for learning	.431	.118	.219	.545									
5 Attitudesto teachers	.416	.138	-.138	.410									
6 General work ethic	.229	-.217	.086	.234									
7 Learner confidence	.124	.438	**.699***	.352									
8Attitudes to attendance	.152	-.120	.407	-.071									
9 Response to the curriculum	.278	-.081	**.560**	.378									

Note: *p<.05, **p<.01, ***p<.001

OME group

Before training, there were no significant correlations of AWMA scores and any of the PASS factors. Six months after working memory training there was a significant correlation between verbal short term memory and Attitudes to Teachers (.53) as well as Response to the Curriculum (.64). There was also a significant correlation between visuo-spatial working memory and Response to the Curriculum (.63).

Comparison group

Before training there was a significant correlation of visuo-spatial short term memory and Self-regard (.64) and Learner Confidence (.70). In addition, visuo-spatial working memory was correlated with Perceived Learning Capacity (.60). Six months after training there were no significant correlations between AWMA and PASS ratings for the comparison group.

Research question 4: What are the effects of working memory training on children's learning identity and attitudes to learning?

Analyses using ANOVAs and t-tests were conducted to investigate whether the children's PASS scores changes in line with the improvements in working memory following the training. The data were analysed with a series of mixed ANOVAs where the between-subjects factor was Group (OME vs comparison group) and the within-subjects factor was Time (before vs after intervention). The F ratios for the main effects and the interactions are given in Table 15. None of the main effects of group or time were significant. Below is reported the exploration of the single significant interaction.

The interaction of Group x Time was significant in the case of the ratings of Self-regard. A plot of the data is given in Figure 16. The effect of group was not significant before intervention, $t(26)=.220$, $p=.828$, but it was after intervention, $t(26)=2.491$, $p=.019$, with the comparison group giving higher ratings than the OME group.

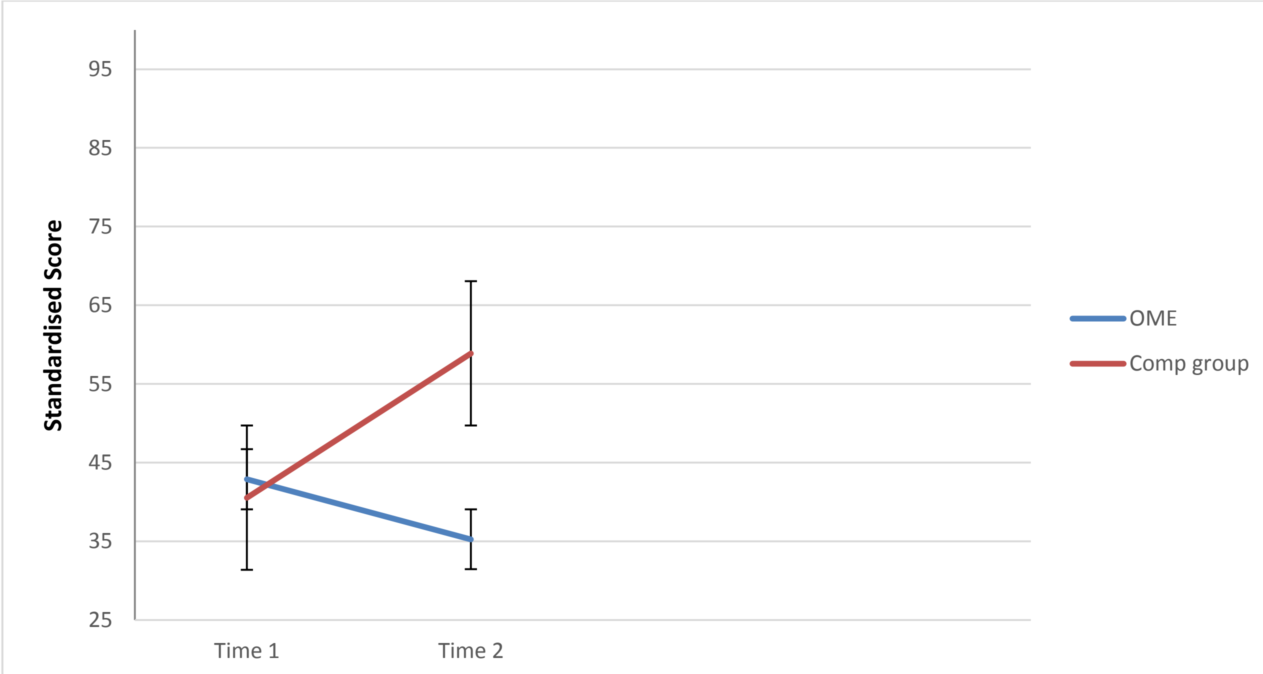

Figure 16: Plot of mean ratings for the PASS self-regard factor for the two groups at the two timepoints

Repeated measures t-tests were also used to examine the extent of any change in PASS factors after training. These revealed that the before intervention-after intervention change was not significant for the OME group or the comparison group for any of the factors. The results from the interviews were examined to attempt to elaborate these findings.

Interview results

Children's responses in the semi-structured interviews were transcribed and perused for patterns using thematic analysis (Boyatzis, 1998). Lists were made of words and ideas which were repeated across different interviews, and sections of interviews containing repeating themes were assigned labels, for example, *negative emotions* and *parents,* then re-examined for ideas underpinning the main theme, creating a thematic map. The ideas arising from the OME group and comparison group interviews were then compared and contrasted to see if there were any common themes, and how the children's concerns varied between the groups. Themes arising from the interviews are shown in Table 18.

Table 18: Themes arising from interviews with OME group and comparison group children

OME group	Comparison group
Negative emotions	Negative emotions
Lack of confidence	Being too busy
Negative relationships with teachers	Benefits of training
Desire to do better in tests	Test confidence
Desire to conform to group norms	Parental pressures
Better retention and recall of text content and number facts	Desire to do better in tests
Parental support	Rewards
	Desire for more help from teachers
	Satisfaction with social aspects of school

While the PASS survey results did not show a significant difference between the two groups, ideas identified from interviews with the children show that, when given more freedom to speak about issues that are important to them, OME and comparison group children appeared to have different priorities. For example, although both OME and comparison group children mentioned negative emotions relating to their experiences at school, for the OME group, these were mainly feelings of anxiety, shame and embarrassment, distancing them from their peers, for example,

I'm a little anxious … (Emily),

I was a bit worried (Mark)

I feel ashamed (Gerry)

I get embarrassed when… (James), while comparison group children mention frustration and anger. For example,

I get angry with myself (Amelia)

when I get stuck I put my hand up, and it's really frustrating when she (the teacher) is helping other people, I never get help (Jess).

The interview data suggest that OME group children were more concerned than comparison group children about how they appeared to their peers, and unfavourable comparisons between themselves and their peers led to negative emotions, while the comparison group children were more concerned with achieving a personal best, or impressing their parents.

Children in both groups mentioned their parents; for the OME group children this was mainly in terms of the support they provided, for example,

when I get home I get helped by my Mum (Leah),

when my Mum explains it at home I find it much easier to understand (Brad)

when I'm doing divisions and I'm doing it one way and mum is showing me another way, it's confusing (Lucy)

my dad was helping me but he didn't tell me the answers (Emily).

Comparison group children mentioned parents in terms of applying pressure, such as expecting them to do extra work, in addition to the homework set, and high expectations of success, such as,

Mum's been challenging me with tests (Amelia)

Dad says, you better pass (Colin)

my Mum pushes me a lot in maths (Kathy)

Mum thinks her methods are best … and she just keeps going (Nat).

Comparison group children also mentioned expectations of rewards for doing well at school, for example,

Mum and Dad give lots of gifts (Nat)

Mum says if I pass I will get a phone (Melody)

my Mum will be really proud of me and get me something (Colin).

OME group children did not mention rewards at all but desired to get better marks in tests to be more like their peers, such as,

if I didn't (do well) I feel ashamed (Melvin),

I get embarrassed when I get low scores (James)

it made me feel they were smarter than me, and I didn't like it (Gerry)

I like to get better marks, for myself, and for what others think… I would do anything to be able to do the work like the other children (Cheryl)

Therefore, the interview data suggest that, for the OME group children, their desire to get better marks, unfavourable comparisons between themselves and their peers, and the negative emotions of embarrassment, anxiety and shame, are all linked to the overriding desire to fit in with their peers. The comparison group children, who already complied with school norms, were subjected to different pressures. Relationships between themes and subthemes for the OME group and comparison group are illustrated in Figures 17 and 18.

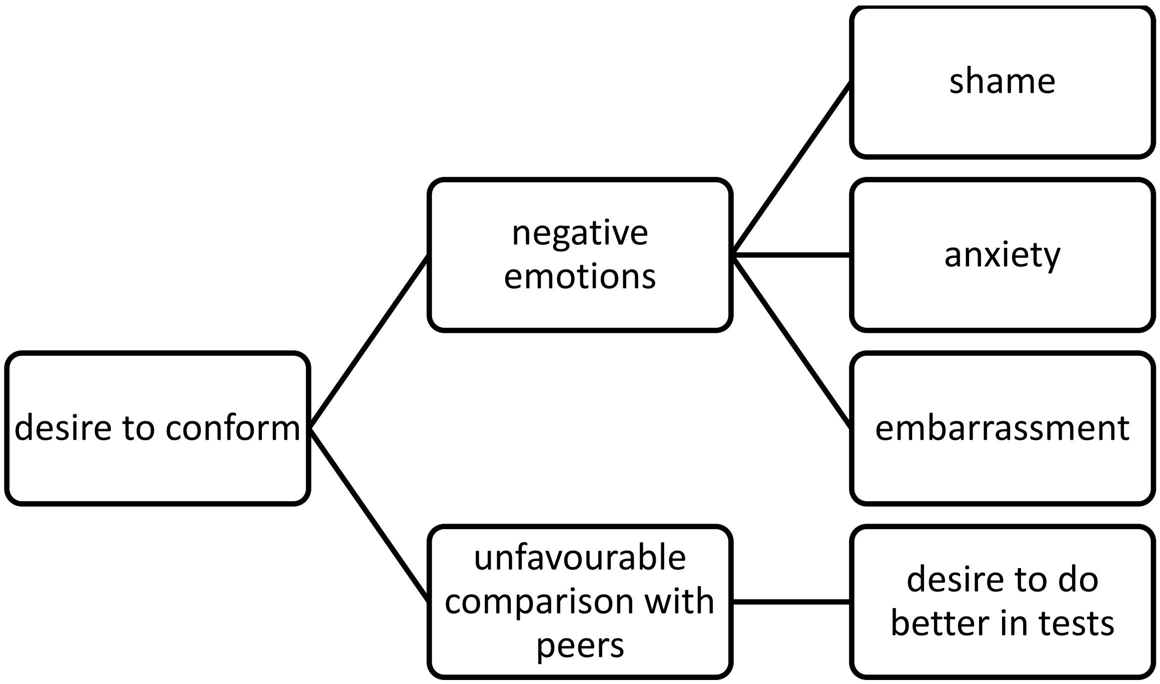

Figure 17. OME group subthemes contributing to the desire to conform

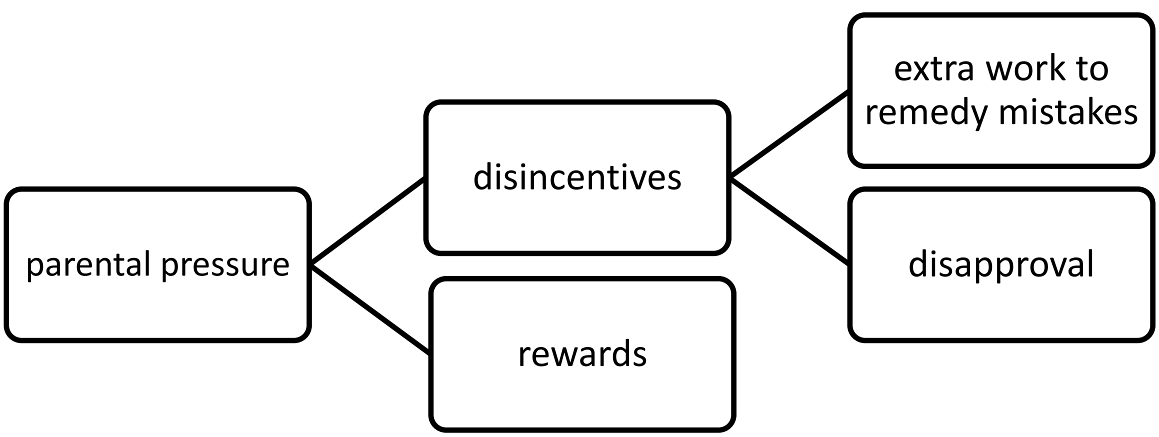

Figure 18. Comparison group subthemes contributing to parental pressure

Supplementary analyses

Correlations between variables at Time 1

It was of interest to explore the inter-relationships between AWMA, Raven's SPM and attainment measures to see whether, for the children in the current study, working memory was more strongly associated with attainment than non-verbal reasoning abilities, as in the study of Alloway and Alloway, (2010).

There was no significant correlation of scores on Raven's SPM with performance on CTOPP, or Progress in English or Progress in Maths for either group, or with scores in TOWRE for the OME group. A significant correlation was observed between Raven's scores and TOWRE single word reading scores for the comparison group.

Table 19 shows correlation matrices for both groups between Raven's SPM, AWMA, CTOPP, single word and non-word reading and pre-training Progress In Maths and Progress In English standardised scores, while Table 20 shows correlations for AWMA and the other measures.

Table 19: Correlations between Raven's SPM, CTOPP, TOWRE, and PIM and PIE for both groups at Time 1

Raven's SPM	***OME Group T1***	***Comparison Group T1***
CTOPP Phonological Awareness	-.050	.322
CTOPP Phonological Memory	.136	.481
CTOPP Rapid Naming	.320	.151
TOWRE Sight Word Reading	.319	.712**
TOWRE Non Word Reading	.414	.467
Progress in Maths	.481	.482
Progress in English	.264	.381

Note: *p<.05, **p<.01, ***p<.001

Table 20: Correlations between AWMA, CTOPP, TOWRE, and PIM and PIE for both groups at Time 1

AWMA	OME Group T1	Comparison Group T1
Verbal STM		
CTOPP Phonological Awareness	.282	.111
CTOPP Phonological Memory	.866**	.750**
CTOPP Rapid Naming	-.358	.459
TOWRE Sight Word Reading	.444	.124
TOWRE Non Word Reading	.392	.328
Progress in Maths	.637**	-.124
Progress in English	.445	-.051
Verbal WM		
CTOPP Phonological Awareness	.255	.438
CTOPP Phonological Memory	.450	.579*
CTOPP Rapid Naming	.168	.080
TOWRE Sight Word Reading	.587*	464
TOWRE Non Word Reading	584*	.602*
Progress in Maths	.749**	..445
Progress in English	.562*	-.251
Visuo-spatial STM		
CTOPP Phonological Awareness	-.254	.087
CTOPP Phonological Memory	.406	.463
CTOPP Rapid Naming	.056	.375
TOWRE Sight Word Reading	.036	.428
TOWRE Non Word Reading	.137	.319
Progress in Maths	.518*	.314
Progress in English	.084	.064
Visuo-spatial WM		
CTOPP Phonological Awareness	.103	.294
CTOPP Phonological Memory	.077	.718**
CTOPP Rapid Naming	.061	.558
TOWRE Sight Word Reading	.267	.395
TOWRE Non Word Reading	.103	.616*
Progress in Maths	.580*	.322
Progress in English	.181	-.292

Note: *p<.05, **p<.01, ***p<.001

AWMA correlations – OME group

AWMA verbal short term memory shared correlations with CTOPP phonological memory (.87) and Progress in Maths (.64). Verbal working memory was correlated with TOWRE sight word reading (.59), and non-word reading (.58), as well as Progress in English (.56) and Progress in Maths (.75). Visuo-spatial short term memory and visuo-spatial working memory were both correlated with Progress in Maths, at .52 and .58 respectively.

AWMA correlations – comparison group

As for the OME group, verbal short term memory was correlated with CTOPP phonological memory (.75). Verbal working memory was correlated with CTOPP phonological memory and TOWRE non-word reading, at .58 and .60 respectively. Visuo-spatial working memory was correlated with CTOPP phonological memory and TOWRE non-word reading at .72 and .62 respectively.

Auditory discrimination and attention test

The effect of group for the Morgan-Barry Auditory Discrimination and attention test was not significant (OME group mean 47.45, sd 14.74, comparison group 53.73, sd=9.84).

Chapter 5: Discussion

Introduction

This study emerged from professional concerns derived from my experiences teaching in the Foundation Stage and Key Stage 1, and supporting individual learners in Key Stage 2, where I had found that identification of and educational provision for children with OME at Bridgeworth School appeared to be neglected. Teachers attributed children's difficulties to lack of attention, poor listening skills and poor concentration, while the children exhibited some behaviours which could be attributed to poor working memory (Alloway et al., 2009), such as forgetting instructions, going off task and interrupting. Previous work into academic progress of children with OME suggested that it delayed reading development (Kindig & Richards, 2000; Peer, 2005; Winskel, 2006), that reading and spelling deficits and inattentive behaviour issues endured well into the teenage years (Bennett, Haggard, Silva and Stewart, 2001) and impacted to some extent on verbal working memory (Majerus et al., 2005; Mody et al., 1999; Nittrouer & Burton, 2005). Poor working memory might be also linked to low self-esteem (Alloway et al., 2009).

In my professional experience, children with a history of early onset OME sometimes struggled with aspects of their work compared with their typically developing peers, particularly with the early stages of literacy, and on-going problems with maths, and these difficulties were a source of unhappiness to the children and their parents. As there seemed to be a degree of overlap in the behaviour of children with poor working memory and those with a history of OME at Bridgeworth School, this study was concerned with whether children with a history of OME had less well developed working memory than their typically developing peers, and if so, were their feelings about themselves as learners also affected.

In my experience as a teacher, a fundamental assumption underlying teaching and learning is that training a particular skill usually produces improvements. It was therefore a small step for me to propose that if children with a history of OME also had poorer working memory than their peers, working memory training might produce improvements in this area, in line with previous research (Dunning, 2012; Holmes et al., 2009), providing these children with better tools to learn with, and leading to more positive feelings about themselves as learners.

This chapter begins by outlining the results for each of the research questions, before discussing the findings in relation to the background literature.

Are working memory capacities of children in this study with parental report of early onset OME different from those of their typically developing peers?

The scores from the AWMA administered before the intervention indicate that there were significant differences in working memory capacities between the OME and comparison group, with the comparison group obtaining higher scores in all four AWMA subscales.

What are the effects of working memory training on working memory, phonological abilities, reading skills and other academic achievements?

Examination of immediate and six month post-training AWMA scores for the OME and comparison groups showed that, for verbal short term memory and verbal working memory, the OME group made significant improvements following the intervention and the differences between the two groups were no longer significant immediately after and six months after the intervention.

For visuo-spatial short term memory and visuo-spatial working memory, both groups made significant improvements after the intervention and the significant difference between the groups persisted immediately after the intervention. However, the OME group continued to improve in visuo-spatial skills so that six months after the intervention, differences between the two groups were no longer significant.

Examination of CTOPP scores showed that both groups made significant gains after intervention for phonological awareness and phonological memory. Six months after training, the OME group continued to make gains in phonological awareness, while the comparison group made a small improvement to CTOPP rapid naming scores.

TOWRE scores after intervention revealed significant improvements for the OME group for sight word and non-word reading, and sight word reading continued to improve six months after training. There were no significant changes to scores for the comparison group after the intervention.

Progress in English scores for the OME group were significantly improved after intervention, but there were no changes for the comparison group in English or maths. Progress in Maths performance was not significantly improved for either group after training and a significant difference between the groups in maths was not observed after training. After working memory training, only verbal and visuo-spatial working memory, but not storage in either area, shared links with Progress in Maths scores.

Are working memory abilities linked with children's learning identities and attitudes to learning in this study?

There were no significant differences in PASS survey scores between the OME group and comparison group before the training. For the OME group, there were no significant correlations between working memory capabilities measured by the AWMA and any of the PASS factors. This suggested that before the intervention, working memory skills did not appear to impact on the OME group children's feelings about themselves and school or attitudes to learning.

For the comparison group, before the intervention, visuo-spatial short term memory was correlated with Self-regard (.64), Learner Confidence (.70) and Perceived Learning Capability (.6). This suggested that children with stronger visuo-spatial storage felt more positive about themselves, were more confident in approaching learning activities and were more certain that they had the necessary skills to tackle new concepts than children with poorer visuo-spatial skills.

What are the effects of working memory training on children's learning identity and attitudes to learning?

For the OME group, six months after training, moderate links between verbal short term memory and Attitudes to Teachers (.53) and Response to the Curriculum (.64) indicated that stronger skills in verbal short term memory were associated with more positive relationships with teachers, as well as greater satisfaction that the work set was a good match for their abilities.

For the comparison group, working memory abilities as measured by the AWMA were not significantly correlated with any PASS factors.

Differences in working memory capacities of children with parental report of early onset OME and their typically developing peers

The findings in this study support earlier work suggesting that there are differences in phonological processing skills, reading and verbal memory between children with a history of early onset OME and their typically developing peers (Kindig & Richards, 2000; Majerus et al., 2005, Winskel, 2006). Some studies have shown that impairments related to OME tend to improve before school (Hall et al., 2007; Roberts et al., 1995; Roberts et al., 2002), and may be subtle (Majerus et al., 2005; Nittrouer & Burton, 2005). Even the most pessimistic view (Bennett et al. 2001), suggests that the physical and educational problems related to OME will resolve by the end of full-time schooling. Where they persist, the magnitude of the difference between affected children and their typically developing peers was generally reported at half a standard deviation or less (Bennett et al., 2001). Differences of .5 (Cohen's *d*) are described as medium effects (Pallant, 2007; Salkind, 2000).

Before training, significant differences between the groups for all AWMA subscales, and CTOPP phonological awareness and phonological memory, suggest that, for the children in this study, effects of intermittent hearing loss due to OME were still visible when children reached the upper primary school years. The significant difference between group means for CTOPP phonological memory was a very good fit with the AWMA differences between groups. This is not surprising, as the CTOPP phonological memory and AWMA verbal short term memory tasks both involved repeating digit strings. Differences in the verbal domain might be explained by interference to auditory processing (Asbjørnsen et al., 2005; Brandes & Ehinger, 1981; Maruthy & Mannarukrishnaiah, 2008), and with impediments to development of phonological coding, resulting from hearing loss during the crucial years for development of phonological awareness and language learning (Kindig &

Richards, 2000; Kuhl et al., 2008: Majerus et al., 2005; Ruben, 1999; Ruben et al., 1999; Winskel, 2006).

Working memory and sight word and non-word reading

OME group pre-training AWMA visuo-spatial short term memory scores were moderately correlated with TOWRE sight word reading (.59) and non-word reading (.58). This finding was not unexpected, given that good visuo-spatial storage would facilitate retention of letter clusters and whole words. Therefore it might be possible that OME group improvements to this area contributed to sight word and non-word reading, which indirectly contributed to improved Progress in English scores. According to Loosli et al. (2012), and Dahlin (2011), stronger working memory was predicted to impact to a greater degree on text level performance, such as reading comprehension, because working with texts, rather than single words, places greater demands on working memory. It is possible that improved reading comprehension underpinned the Progress in English gains for both groups, as Progress in English includes a comprehension section.

Working memory and maths and English

For the OME group, pre-training AWMA scores were moderately to strongly correlated with Progress in Maths, but only verbal short term memory shared a moderate correlation with Progress in English. Correlations between AWMA scores and Progress in English or Progress in Maths scores for the comparison group were absent. This suggests that, for the OME group, poor working memory capacity, was likely to result in lower maths attainment. This accords well with the findings in the literature, that children with poor working memory, particularly, visuo-spatial working memory, often experience difficulties with maths (Alloway et al., 2009; Zheng et al., 2011). However, for these children, improvements to AWMA scores following the intervention did not lead to improvements to their standardised scores for Progress in Maths, administered six months after the intervention. Possible reasons for this are discussed in the next section.

Working memory and phonological processing

Phonological awareness tasks place a load on working memory, depending on task complexity, as shown by Oakhill and Kyle (2000). Children in both groups in this study found CTOPP phoneme deletion more difficult than phoneme blending, although as demonstrated by Oakhill and Kyle, phoneme deletion tasks are less taxing for working memory than sound categorisation tasks, where words have to be held in mind before a judgement can be made about them. OME group children had poorer phonological awareness scores before training, with a far smaller proportion, 12.5% against 50% in the comparison group, attaining in the above average range. OME group phonological awareness scores shared weak, non-significant links with sight word and non-word reading. OME group children were also significantly poorer than the comparison group children at the TOWRE non-word reading task, according to the pre-training independent sample t-test.

The OME group, with significantly poorer verbal and visuo-spatial working memory, might reasonably have been expected to be slower at visual feature analysis of a word, where letters are identified and matched to phonological codes to be spoken aloud, without the support of the semantic system, when reading aloud familiar single words, and retrieving phonological codes for letters, then blending them to pronounce non-words, as illustrated by the lexical and sublexical routes of the DRC (Coltheart, 2006). The primary difficulty for the OME children was (presumably) interference to the incoming speech signals during their early years, which may have affected development of phonological prototypes (Kuhl et al., 2008) and language skills. But for these children, taught to read mainly using a synthetic phonics method, with strong exposure to high frequency sight words and explicit links made between reading and writing, their ability to read high frequency sight words in the TOWRE test was not significantly different from that of their peers. However, the comparison group children with stronger working memory abilities, were able to use their stronger phonological awareness skills to a greater extent, evidenced by moderate links between phonological awareness and both sight word reading (.62) and non-word reading (.65), which were absent for the OME group. Therefore, although the OME children in the current study were disadvantaged in comparison to their typically developing peers in terms of phonological processing and working memory, as predicted by the literature (Kindig & Richards, 2000: Majerus et al., 2005; Nittouer & Burton, 2005; Winskel, 2006), the actual impact this had on school attainment for the group as a whole, as measured by standardised tests, was small.

Working memory abilities and developing learning identities and attitudes to learning

Feelings about self and school, including the development of a learning identity, depend on many different factors. These include personal relationships as well as academic progress. The current study acknowledges the role of relationships in creating a sense of well-being at school, but suggests that at Bridgeworth School, where there is such a high emphasis on academic success, children’s classroom performance might impact on their feelings, with academically successful children feeling more positive. Studies have shown links between working memory and school success (Alloway & Alloway, 2010; Alloway et al., 2005; Gathercole et al., 2004), including links between working memory and measures of intelligence, while also suggesting that working memory is a better predictor of later attainment than intelligence tests (Alloway & Alloway, 2010). Low working memory has been linked with poor self-esteem (Alloway et al., 2009). The current study sought to add to current understanding about how working memory might be linked to children’s feelings of well-being, and positive views of themselves as learners.

Working memory and learning identities and attitudes to learning: individual OME group profiles

As previously mentioned, no children in the current study had identified learning difficulties, and difficulties were relative, in comparison to the progress of typically developing peers. Individual OME group children’s pre-training AWMA profiles were different, as were their patterns of academic difficulties. Some children experienced difficulties with English or maths, some with both, and three, Jenna, Gerry and Nathan, had no particular problems with either. The pattern of difficulties experienced by the OME group children, together with weaknesses in working memory, sight word reading, non-word reading, phonological awareness, rapid naming and class performance are shown in Table 21.

Table 21: Individual problems for OME group children

Name	English PIE	Math PIM	Verbal STM	Verbal WM	Visuo-spatial STM	Visuo-spatial WM	Sight word reading	Non-word reading	PA	RN	Class English	Class Maths
Gerry**	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Nathan****	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Jenna***	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
Lucy*	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Red
Emily*	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green	Green	Red
Sally*	Red	Green	Green	Green	Red	Green	Green	Green	Green	Green	Green	Red
Melvyn*	Red	Green	Green	Red	Green	Green	Green	Green	Green	Red	Red	Green
Victor**	Red	Green	Red	Red	Green	Green	Green	Green	Green	Green	Red	Green
Tyler***	Green	Green	Green	Red	Green	Green	Green	Green	Green	Red	Red	Green
Mark***	Green	Green	Green	Green	Green	Green	Green	Red	Green	Green	Red	Green
Ryan***	Green	Green	Red	Red	Green	Red	Green	Red	Red	Green	Red	Red
Harold****	Red	Red	Red	Red	Red	Red	Green	Green	Green	Green	Red	Red
Brad*	Red	Green	Green	Red	Green	Green	Green	Green	Green	Green	Red	Red
Cheryl***	Red	Red	Red	Red	Green	Red	Green	Green	Red	Green	Red	Red
Leah*	Red	Green	Red	Red	Green	Green	Green	Green	Green	Green	Red	Red
Angel**	Red	Red	Green	Red	Red	Green	Green	Red	Green	Red	Red	Red

Red cells denotes low standardised scores below 95 Green cells denote average to good scores

Severity of OME: *1 or 2 episodes, **2 or 3 episodes, ***several episodes, ****severe and persistent

Children with no difficulties with the curriculum

The three OME group children with no particular difficulties with their school work also had no AWMA scores within the deficit range, and only one PASS score, for Gerry, in the vulnerable range below the 20th percentile. Gerry had poorer pre-training visuo-spatial working memory in relation to his other AWMA scores and a particularly low rating of 8.6% for Learner Confidence. Gerry's interview responses revealed that he worried about his performance in class and in tests but apart from Learner Confidence, his other PASS scores were fairly positive. Children with stronger working memory capacities in this study were not likely to hold particularly negative views about themselves as learners.

Children with difficulties with English and maths

The OME group children with stronger working memory capabilities had fairly robust PASS ratings, and I expected to find that children with the greatest working memory deficits would hold less positive feelings about themselves as learners. However, of the six children experiencing problems with maths and

English, only three children rated any PASS factor below the 20th percentile. For Leah these were Perceived Learning Capabilities, Attitudes to Teachers and Learner Confidence. For Harold these were Attitudes to Teachers and Feelings about Self and School. For Cheryl, Perceived Learning Capabilities, and for Brad, Feelings about Self and School, were the lowest rated factors. Three of the six children rated Perceived Learning Capabilities as their lowest score. These findings suggest that some of the children with the most severe working memory deficits, and difficulties with English and maths, appeared to be aware that they lacked some necessary mental tools required for learning. The impact of this awareness affected general feelings of safety and security at school, confidence in themselves as learners and relationships with teachers, but did not impact on the children’s feelings about other aspects of their school experiences.

Leah experienced difficulty hearing sounds in words, and remembering words in sentences when writing. She would leave out letters from consonant clusters and leave out words from sentences. Overall, her writing was underpinned by good ideas and appropriate vocabulary, but suffered from ungrammatical sentences, lack of punctuation and poor spelling. Harold and Leah had different pre-training AWMA profiles, but similar academic problems. In maths, Harold and Leah found it impossible to learn their multiplication tables, number bonds and paper and pencil arithmetic techniques, for example, column addition or subtraction, particularly involving exchange. Harold could not subitize, or perceive without counting, arrays of objects greater than three, or less if this followed an operation such as addition or subtraction. In shape, space and measure, they could not identify different types of angle, rotated or reflected shapes, describe routes and directions, and telling the time beyond o’clock was impossible. In literacy, their main problems were decoding unfamiliar words, learning and applying spelling rules, reading fluency and comprehension, and writing composition. Harold could learn his weekly spellings as sets of individual words, but could not recall shared spelling patterns, generalise them to other similar sounding words, use them correctly in writing composition, or retain spellings for high frequency words. For Harold, *said* was always *sed*, *was* was *wos*, and *put* was *poot.*

Brad stated in interviews that he often felt angry with his teacher because he did not understand whole class explanations, and was unhappy with the teacher's responses to his requests for help. His teacher, on the other hand, viewed Brad's frequent interruptions as disruptive and would have preferred him to remain in his seat. In this instance, a breakdown in communication had occurred, as Brad thought that he was taking the correct action to seek help, but his teacher felt that his main barrier to learning was not sitting down and listening.

Children with difficulties with maths

Of the three children with difficulties restricted to maths, Sally and Lucy, were no more negative about themselves and school than those with no particular difficulties. Sally had low average pre-training verbal and visuo-spatial storage, and demonstrated similar problems in maths to Harold and Leah. She held very negative feelings about her safety and security at school before training, with a very low rating at the 3.8th percentile. Lucy, with no specific weaknesses in AWMA, CTOPP or TOWRE scores, struggled to learn basic skills in maths, such as number bonds, multiplication tables and sequences, and rated only Attitudes to Attendance below the 20th percentile. For these two children, difficulties with maths did not appear to have a significant impact on their overall learning identity. However Emily, with low average pre-training verbal short term memory, struggled with all aspects of maths, including processing maths language, and visuo-spatial aspects such as telling the time. Emily had PASS scores below the 20th percentile for all nine factors. She also demonstrated some problems with phonemic discrimination on the Morgan-Barry Auditory Discrimination and Attention Test (1988), achieving a very low score, although her difficulties identifying phonemes had not impacted on her sight word reading, nonword reading, or Progress in English throughout the study. These findings suggest that the combination of poor verbal and visuo-spatial storage and difficulties with maths might not necessarily have a negative impact on children's learning identity. Emily's negative feelings might have been connected with underlying phonological difficulties, as her PASS profile had more in common with other children in the study with difficulties with English, than the other children with maths difficulties.

Children with difficulties with English

Four children, Mark, Victor, Melvyn and Tyler, had difficulties restricted to English. Mark and Victor had scores below the 20th percentile for five factors, Melvin for two factors and Tyler for one factor. All four children had very low Self-regard, two had low scores for Perceived Learning Capability, General Work Ethic and Response to the Curriculum. Attitudes to Teachers, Learner Confidence and Preparedness for Learning were each rated below the 20th percentile by different children within this group. Mark's pre-training scores were at least low average for most measures, with relatively weak phonological awareness and poor nonword reading skills, evidenced by his poor pre-training TOWRE nonword reading score. He found it difficult to decode unfamiliar words as he lacked the ability to retrieve sounds for letters and store them for long enough to blend them into words, but his text reading was better when he could use context to guess new words. This meant that reading was not always accurate but he was able to get the gist of texts with simple or compound sentences. His verbal short term memory and verbal working memory scores were not particularly poor, but his phonological awareness scores indicated that his phonological processing was not reliable at the phoneme level, although he could manipulate syllables. This suggested that his phonological representations were not sufficiently fine grained at that time to enable him to blend and segment sounds in words efficiently (Masterson et al., 2005) and his awareness that he lacked some necessary skills for reading and writing impacted on his Perceived Learning Capability, General Work Ethic, Attitudes to Teachers, Self-regard and Preparedness for Learning.

Victor and Melvin had noticeable difficulties with English at school, particularly learning spellings. Victor had very poor verbal short term and working memory, and had experienced a slow start with learning letters and sounds, leading to school-related anxiety. The effects of these early problems were still apparent in his Self-regard and General Work Ethic, Perceived Learning Capability, Learner Confidence and Response to the Curriculum scores in Year 5. Melvin, with poor verbal working memory, had poor Self-regard and Response to the Curriculum before training, both below the 2nd percentile.

Tyler had some slight weaknesses in English classwork, possibly related to his poor verbal working memory AWMA scores, although teachers were not concerned. He also had a poor rating for Self-regard before training which was below the 20th percentile.

It seems from an examination of these profiles that difficulties with English had the greatest impact on children's Self-regard. Children with difficulties restricted to English were also more likely to be negative about other PASS factors, particularly General Work Ethic, which includes feelings of anxiety, and Perceived Learning Capability, suggesting that the children were aware that they lacked certain necessary skills. Children with difficulties across the curriculum appeared to have a less fragile image of themselves as learners than those such as Emily, Victor and Mark, whose difficulties were restricted to one curriculum area.

Post-training changes to individual profiles

After working memory training, most children in the comparison group were more positive about their Perceived Learning Capability. This means that they felt more positive about their skills for learning. Only two children in each group reported no change in their feelings on this scale, while two children from each group reported less positive feelings. Gerry, from the OME group, said about this,

> *"when it started my friends were getting high scores and I wasn't… it made me feel they were smarter than me and I didn't like it… Now I am better at remembering stuff."*

For Gerry, Progress In English and Maths scores decreased between 2011 and 2012, but showed upward progress in 2013. Nevertheless, his post-training PASS scores were generally the same, but upward movements for General Work Ethic, Learner Confidence and Attitudes to Attendance suggested that after training, Gerry was less anxious about his work, enjoyed school more and had greater confidence as a learner. Gerry had poorer pre-training visuo-spatial working memory in relation to his other AWMA scores, and his pre-training worries could be interpreted in relation to the work of Bourke et al. (2013), where it was found that visuo-spatial working memory capacity was linked with early writing skills. Gerry had struggled with literacy tasks at the beginning of formal schooling, which had affected his dispositions and attitudes in a similar way to the child participants in Bibby (2008; 2011) and Lever-Chain (2008), particularly in relation to Learner Confidence, which was rated at the 8.6^{th} percentile before training. After training, Gerry's visuo-spatial working memory was greatly improved, in line with his other AWMA scores. CTOPP phonological memory and rapid naming, and TOWRE non-word reading scores were also improved, along with Leaner Confidence. However, for Gerry, his overall feelings about himself and school, particularly Self-regard, Preparedness for Learning and Response to the Curriculum were much less positive.

Nathan summed up improvements to his learning capabilities as,

> *" comprehension, before I would have had to read the text several times, and then look back before answering every question. Now I can remember details without checking back every time. I can remember more instructions, before I used to miss the slightest bit out, but now I can work out what the missing bits should be*."

Nathan's AWMA, CTOPP and TOWRE scores were all improved after training, as were Progress in English and Progress in Maths scores, and scores for five of the nine PASS factors, Perceived Learning Capability, Self-regard, General Work Ethic, Learner Confidence and Response to the Curriculum. In Nathan's case, gains in attainment in English and maths were linked with lower levels of anxiety, greater satisfaction with the difficulty level of work set, improved self-regard and confidence, as well as perception that current knowledge and skills were sufficient to cope with new work.

Brad reported that he could "*do it faster, I know my number bonds better…and I can think more words*."

After training, Brad's AWMA scores were all within the average range. CTOPP phonological awareness and TOWRE sight word and non-word reading were all improved, along with end of year Progress in Maths and Progress in English attainment, but his feelings about himself and school remained ambivalent. While his feelings of safety and security in school, perceived learning capability and confidence as a learner were more positive, his feelings of self-regard, relationships with his teachers, levels of anxiety, desire to be at school and feelings about the match between the work set and his academic abilities were less positive at the end of 2012.

Several children reported improvements in being able to remember the content of a comprehension passage while attempting the questions, and as reading comprehensions forms a large part of the literacy curriculum at Bridgeworth School, any improvements in their abilities to participate in these lessons have made real differences to their feelings of being able to contribute to the group, and have led to an increase in favourable interactions with teachers during these lessons, noted by Harold, "*It feels really weird, Mrs Light says I'm doing quite fine*."

Responses to Preparedness for Learning revealed a different pattern, with nine children in the OME group reporting less positive feelings, and far fewer children reporting more positive responses. Group means were also lower for both OME and comparison groups at the end of the study. One possible reason for this, mentioned by Cheryl and Brad, is that the children realise that the work keeps getting more difficult, so new skills are of limited value when the children are always in the process of catching up. Cheryl said that she

> "*would try anything to be able to do the work like the other children*,"

and her aim was to get better marks, because of "*what others think*." The position could be summed up by George, "*I think it's just the work getting harder*…", or Emily,

> "*When I look around… I'm only on the first question and everyone else is finished, that makes me feel sad*,"

For Cheryl, even though after training all AWMA, CTOPP, TOWRE and Progress in English and Progress in Maths scores were improved, her feelings about herself and school, with the exception of Perceived Learning Capability, were very much less positive at the end of 2012. Therefore, even though Cheryl was aware that her skills had improved, she understood that the work set was still too hard, which increased her anxiety and had a negative impact on her self-image as a learner.

Changes in General Work Ethic, which includes motivation and levels of anxiety, revealed that over half of the children in each group were more positive after training, while responses to Learner Confidence, which indicates attitudes to new and challenging work, were similarly more positive overall for both groups. Most children, after working memory training, felt more positive about their prospects, although a preoccupation with tests was evident amongst the comparison group children and largely absent amongst the OME group children. Kathy, a high achieving comparison group child, summed up general comparison group attitudes to work as,

> "*I'm confident to attack anything we're given, I think it's easy, as long as we've covered it*."

Several comparison group children echoed the point of being prepared for tests by constant practice, while tests were generally less important for children in the OME group, who were more concerned about their day to day school work.

Children in the OME group showed the greatest levels of change in their attitudes to teachers, reflected in survey Factor 5, this change being more greatly in evidence for the younger children, where there was a 19 percentile point improvement in mean scores. However, for some children, relationships deteriorated during the year. For example, according to Brad,

> "*I don't really like the teacher, she doesn't explain things well… and when you've done something a little bit wrong, she shouts at you. I feel angry with her, but I can't show it, I have to be angry in my head and I can't really work better. I just try and be good*."

Brad confused being good with doing good work, and he found it very difficult to separate the teacher's judgements about his classwork from judgements about him as a person.

In the comparison group, Leon, who had demonstrated negative feelings in relation to six PASS factors, was more positive after training, particularly in relation to Self-regard. His AWMA scores were also greatly improved after training. Most comparison group children showed no change in their feelings about the teacher/pupil relationship, while only three felt more positive and three less positive about their teachers. This indicates that for the comparison group, relationships with teachers were more stable and depended less on the child's perception of classroom performance. As previously mentioned, the greater volatility in their relationships with teachers expressed by the OME group, seemed to depend on the recent communications between pupil and teacher. Rapid changes in feelings towards teachers were also noted by Bibby (2011), where pupils at Grafton School were overheard to swear under their breath about the teacher while she was ignoring them, and a few minutes later bask in pleasure at a throwaway compliment. Bibby's children often felt that they were not good enough, and this was the same for children at Bridgeworth School. Gerry said,

> "*It depends on how well I did, if I did well, I think good, if I didn't I'd be ashamed, so usually everyone else gets good marks and me and Mark get worse marks – I think that everyone else is more confident, I worry.*"

Melvin reported concerns when having to call out his spelling and maths test scores in class,

> "*I feel embarrassed when I get low scores – I don't worry so much now, because they are better, but sometimes Olive says her scores in a sort of crying voice.*"

Melvin had very poor verbal working memory to begin with, but after training all AWMA scores were very good. CTOPP scores, particularly rapid naming, were improved, along with sight word and non-word reading. Progress In English and Progress In Maths were improved for 2012, and gains for Progress In Maths continued for 2013. After training Melvin felt greater positivity for Self-regard, General Word Ethic and Response to the Curriculum, while Attitudes to Attendance remained the same. Melvin was less anxious after training, and felt that the work set was a better match for his abilities, which resulted in more positive image of himself as a learner, notwithstanding that in other areas such as relationships with teachers, feelings of safety and security at school, perception of learning skills and confidence as a learner, he was less positive.

After training, Mark's AWMA, phonological awareness and phonological memory, sight word and non-word reading showed gains, but non-word reading fell back six months after training. Progress in English scores decreased between 2011 and 2012, but recovered slightly by 2013. Progress in Maths showed no change from 2011 to 2012, and improvement from 2012 to 2013. Mark was neither more or less positive overall after training, with less positive feelings for Self and School, Learner Confidence, Attitudes to Attendance and Response to the

Curriculum balanced by more positive feelings about Perceived Learning Capability, Self-regard, Attitudes to Teachers and General Work Ethic, while Preparedness for Learning showed no change. This suggested that after training he felt less safe and secure at school, was less happy to come to school, and felt that the work set was not a good match for his skills and understanding, though he felt more positive in terms of his self-image, learning skills, anxiety levels and relationships with teachers. His performance on the Morgan-Barry auditory attention and discrimination test was particularly poor, with 13 errors, leading to a z score of -2.6, while all other children apart from Emily, who made the same number of errors, made either no errors, or only as many errors with particular sounds as would be expected from typically developing children of their age. Depressed hearing levels, or intermittent hearing loss could have interfered with the development of speech sound prototypes (Kuhl et al., 2008) for Mark and Emily, which would have impacted on their ability to hear and identify sounds in words, to create phonological codes for those sounds, and to store them in phonological memory (Majerus et al., 2005; Maruthy & Mannarukrishnaiah, 2008; Mody et al., 1999). Information about the development of auditory processing and discrimination skills for the children in this study is not available apart from the assessment carried out in 2013. Therefore it is not possible to say whether or not, or to what extent, children were affected prior to this.

Before working memory training, Harold had very little understanding of the number system, but after training, there was an immediate improvement in that he would see the pattern after only two or three attempts counting along a number line. He was then able to immediately transfer the new knowledge into a different form. After training, his previously very low AWMA scores were much improved, although verbal short term memory remained poor. Phonological awareness and sight word and non-word reading improved, as did Progress in English and Progress in Maths scores for 2012, however, both Progress in English and Progress in Maths decreasedl at the end of 2013. Harold's feelings about self and school were very much more positive at the end of 2012, with only scores for Self-regard and General Work Ethic showing no change. This suggested that his self-image and levels of anxiety had not changed, although he was happier to be at school and believed that his knowledge and skills were better suited to the work set than before training.

Emily, who along with Mark, had the greatest difficulty with the Morgan-Barry Auditory Discrimination and Attention assessment, improved her AWMA scores following training, along with CTOPP and immediate post training TOWRE scores, but TOWRE scores decreased six months later, with non-word reading remaining poor. In 2012, Progress in English and Progress in Maths scores improved, but decreased for 2013. Emily's feelings about herself and school, while mostly still below the 40th percentile, were more positive after training.

Leah improved in all AWMA, CTOPP and TOWRE scales after training, but non-word reading scores decreased , while remaining within the average range six months after training. Progress in Maths and Progress in English scores showed sustained gains for 2012 and 2013, and scores for all PASS factors except Self-regard were more positive after training. Leah's self-image and confidence as a learner was improved after training, to the extent that she volunteered to undertake extra work, confident that this would impact on her progress.

Working memory and learning identity

The pre-training working memory, phonological awareness and non-word reading differences between the OME group and their typically developing peers in this study in terms of standard deviations were large to very large, while differences between them in terms of their feelings about self and school were less clear cut. While children's feelings about themselves and school did not differ by group, when children in the OME group were looked at as individual cases, it was apparent that some children with poor working memory suffered from poor self-image in a learning context, and this was ameliorated after training. Children's attitudes to themselves and school did not appear to be strongly associated with working memory when AWMA and PASS scores were examined, it was clear from observations of children at work and individual profiles that those with relatively poorer working memory faced greater challenges in daily lessons than their typically developing peers, and that some of these children expressed negative feelings relating to their metacognitive understanding of themselves as learners, particularly their confidence in their ability to learn. From this, it can be concluded that working memory abilities may be linked to a certain extent to developing learning identities and attitudes to learning, but that other individual characteristics and interpersonal relationships between pupils, teachers and parents mean that determination of the precise nature of this relationship is problematic. This section examines working memory, learning identity and attitudes to learning by examining the links between working memory and the pupils' attitudes to self and school survey, and strength of links between working memory and learning identity and attitudes.

For the OME group, there were no significant pre-training correlations between working memory and any survey scores, and for the comparison group, visuo-spatial short term memory was moderately well correlated with Self-regard and Learner Confidence, and visuo-spatial working memory was moderately well correlated with Perceived Learning Capability. As low capacity in visuo-spatial short term memory and working memory is associated with attention and concentration problems and difficulties with maths, together with lower levels of self-esteem (Alloway et al., 2009; Eysenck et al., 2007), it seems reasonable to anticipate that stronger abilities in these areas might engender more positive feelings in terms of confidence. Learner confidence might be impacted by how well equipped for learning they feel themselves to be.

It is not clear why any significant relationships between working memory and feelings about self and school should be absent for the OME group before training. Examination of the profiles in the previous section revealed a connection between difficulties restricted to English and low ratings for Self-regard, whereas children with difficulties with just maths, or English and maths, were more likely to provide the most negative ratings for Attitudes to Attendance, Feelings about Self and School, and Perceived Learning Capability. From an examination of Table 21 and the individual profiles, it appears that the severity of working memory deficits is not necessarily linked with negative dispositions and attitudes at school, as the children with the greatest working memory deficits and most wide ranging classroom difficulties were not the most negative about themselves and school. Perusal of PASS scores among the comparison group revealed that one child, Leon, with low AWMA scores across all four sub scales, had ratings below the 20^{th} percentile for seven of the nine PASS factors. However, Leon's low AWMA scores were unrelated to his achievement in English and maths, and the difficulties he experienced at school were related to social and communication issues and inappropriate behaviour, as well as attention and concentration problems in class, which might have been linked with his poor working memory.

As previously mentioned, there were no significant differences between the OME and comparison groups for any of the survey factors before or after training, but there was a large amount of variation within and overlap between group scores. The emergence of feelings of low Self-regard are difficult to explain in terms of the children's performance on the attainment measures used in this study, as differences in performance between the groups disappeared after training. The children were aware of their improvements, therefore it might be expected that they should have felt better about themselves as learners. However, these tests measure attainment, not effort. Processing Efficiency Theory (Eysenck et al., 1992; Hadwin et al., 2005; Ng & Lee, 2010; Owens et al., 2008) mentions task effort and attainment, and perhaps the amount of effort children in the OME group had to expend to achieve similar results to their typically developing peers could account for the apparent difference in Self-regard, and would explain Cheryl's continuing negative feelings about herself despite considerable academic progress.

For Harold and Leah, their feelings about themselves as learners were very much linked to their most recent interactions with their teachers. Harold did not want to be seen as different from the other children and refused to use apparatus supplied by the teacher to help with maths in class, because the other children did not use them. He preferred to risk teacher disapproval for not using the apparatus, than risk further distancing himself from his peer group. Nevertheless, he had good attitudes to attendance, indicating that he enjoyed being at school and felt close to the others in his class. Harold was achieving at a much lower level than his peers in maths. While the others were doing column addition and subtraction with hundreds, tens and units, at the beginning of September, 2011, Harold was still working on an understanding of number relationships within 20.

His reluctance to appear different from his peers was illustrated by his behaviour during a maths lesson in early September, 2011, Harold's task was to add a single digit to ten, and record his answers. Despite having a 100 square in his tray, and being reminded to take it out, he did not use it, and for each calculation, counted out the number to be added on his fingers, then started from ten, adding the numbers on by touching and counting the fingers raised. This caused problems when he needed to use the fingers of both hands, as he would sometimes forget how many fingers were to be counted and have to start again. When recording his answers, he did not review them or notice a pattern, until I asked him to look at the pattern of answers, with specific attention drawn to the number added and the unit portion of the answer. He reviewed each of his answers with no sign of comprehension, until reaching 10+8, he looked up with a smile and said, "*I know that, it's 18*." He was then able to write the answer for 10+9 without working it out. When asked to look at the calculations another way, by adding 10 to a single digit, and directed to locate the answer on a 100 square, he counted on 10 each time, and could not locate the square containing 10 more, directly underneath the first digit, even when this was explicitly modelled. During subsequent lessons, Harold worked on the same calculations, and each time, he was initially unable to remember the relationships between numbers and the patterns of answers when adding 10.

Harold was equally poor in other areas of maths, namely calculations involving money, and telling the time. He found it very difficult to separate the value of an array of coins from the number of coins in the array, and could not understand the concept of giving change. If asked how much change there would be when spending any given amount, he would reply with the amount spent, for example, *You buy a sweet for 6p. What is your change from 10p?* Harold would say the change was 6p. On one occasion the class was working on money and change. Harold had a worksheet involving giving change within five and ten pence. As Harold did not know his number bonds, he was not able to see any relationships between the cost of items and the amount of change, and despite having a 'counting on' method demonstrated to him on several previous occasions, was not able to count on by himself. He was given one penny coins to provide a visual indication of the change but did not touch them. When I began to help him and set out the coins in a line in front of him, and physically counted and moved the number of coins spent, he was not able to see how many coins were in the change portion of the array, and needed to touch them to count them. Once he began to count the coins, he forgot what he was doing and gave what appeared to be random answers. This behaviour is likely to be related to problems in verbal and visuo-spatial memory domains, as Harold lacked the capacity to remember verbal strategies like counting on, or visual strategies like recording steps on a number line, and could not see at a glance the number of items in an array. As soon as he started counting, focus on his goal was lost, and he was unable to retrieve it.

Sally, Leah and Emily were not as poor at maths as Harold, and could be set the same work as the main class, but struggled to understand new ideas. They had particular difficulty with mathematical vocabulary and would often make mistakes because they had not understood terms such as '*the sum of*', or '*how many more than … is …*' and '*what is the product of…*'. They had a poor knowledge of multiplication tables and needed to go through a whole table to recall multiplication facts, which sometimes caused them to forget where they were in working out a problem, so that they would write the answer to the multiplication calculation as the answer, even if the problem required another step. They also demonstrated a poor understanding of addition and subtraction with exchange, with the latter being particularly challenging if the number to be subtracted from contained a zero. In this case, they would put zero as the answer. Where exchange was required, they would avoid this by subtracting the smaller from the larger number each time.

These difficulties in maths, which were not experienced by the class as a whole, impacted on these children's image of themselves as learners. Because the work was regularly too difficult for them, they were not confident that they had the tools to learn effectively, and saw the problem as a personal characteristic, rather than a problem with the work. They were also unable to assess their own progress in this area and were reliant on teacher judgements, so if the teacher expressed disapproval, they would become upset, but on another occasion they would enjoy the teacher's approval if paid a compliment. This could also account for negative feelings about teachers arising from interviews with OME children, but not comparison group children, who were largely positive in their comments about teachers. For Harold and the other children with poorly developed visuo-spatial capabilities, using apparatus which would appear to the teacher to clearly show how to identify answers to addition and subtraction problems did not necessarily help, because they were not able to see, or assign verbal labels, to even small quantities and needed to count every time. These children were not oblivious to a sense of exasperation from the teacher, and they were also aware that other children were able to see the answers without counting every time. Understanding that they could not do something the other children found simple, no matter how hard they tried, was damaging to their development of a positive learning identity.

Problems within the verbal working memory domain were greatly in evidence among children with difficulties with English, which accords with studies in the literature, for example, Swanson and Jerman (2007), where it was found that verbal working memory growth was strongly aligned with progress in reading comprehension, while phonological abilities played a less significant role. In the current study, only Harold, Ryan and Cheryl suffered from poor phonological processing, and it is interesting that the three children with poor rapid naming skills, Angel, Tyler and Melvin, also had poor verbal working memory and general problems with English. Perhaps, like the children in the Swanson and Jerman study, it is possible that the OME group children were able to compensate for some of their difficulties by developing strengths in other areas, but particular combinations of difficulties presented barriers to learning against which compensatory strategies were ineffective.

Chapter 6: Conclusions

Links between working memory and OME

For the children in this study, working memory limitations, particularly in the verbal domains, were more likely to be found in the OME group than the comparison group. This suggests that working memory differences were still apparent between OME and comparison groups, even when the children had experienced rigorous phonological awareness and phonics training, within a language-rich curriculum, from nursery onwards, as prescribed by the Statutory Framework for the Early Years Foundation Stage (Department for education and Skills, 2007). Immediate and six month post-test results for working memory and phonological processing assessments confirmed the diminishing differences between the groups, for all the children.

Working memory training effects

Improvements in AWMA scores showed clear improvements in targeted areas, as expected in line with earlier research. The working memory intervention training effects for measures of working memory for the OME group were significant and large, while for the comparison group, only improvements to the visuo-spatial domain were significant or large. Overall, on the majority of measures, the OME group made greater progress than the comparison group in terms of effect size. Improvements, or ‘catch-up’ by the OME group cannot necessarily be expressed in terms of the magnitude of the differences between the groups, or even the significance of the differences between the groups after training, as the training impacted on and improved the performances of both groups. However, narrower differences after training suggest that the intervention was more effective for children with lower working memory abilities to begin with, in line with Dahlin (2011). Children with lower initial scores improved the most, possibly because the OME group’s low initial verbal memory scores allowed more room for improvement than the comparison group’s higher initial scores.

In this study, working memory training appears to have ‘normalised’ scores for the OME group within the verbal domain of working memory. ‘Normalisation’ refers to the similarity of OME group means on measures after training to comparison group means before training. This could be interpreted in the context of Berninger and O’Malley May’s (2011) study, where it is reported that brain imaging after successful interventions shows normalised function of certain brain areas. According to Berninger and O’Malley May (2011), normalisation may be short lived, as connections between brain areas may not have been established and the individuals may still be vulnerable to new and different manifestations of their original problem.

Shipstead et al. (2012) suggest that improvements to working memory tasks following training might be attributed to practice effects, as participants get better at doing the same, or similar things, over and over again. Improvements to CTOPP sub-test scores might be attributed partly to practice effects, as there are no parallel forms of the tests and it was administered three times within one academic year. However, the rapid naming task seemed to become more difficult for some children, who became slower as they attempted to employ strategies to avoid breakdowns in retrieval. CTOPP improvements could relate to training effects, as phonological awareness and phonological memory tasks depend partly on verbal storage and verbal working memory (Dahlin, 2011; Loosli et al., 2012; Oakhill & Kyle, 2000). The CTOPP phonological awareness tasks used in this study test the ability to elide a phoneme from a word to create a new word, and to blend sounds to make words. The elision task begins with removal of a syllable from a two syllable word and progresses through deletion of initial, final and medial sound to removal of one part of an initial, final or medial consonant digraph or trigraph. The blending task progresses from two to ten phonemes. As previously mentioned, phoneme deletion has been shown by Oakhill and Kyle (2000) to be less demanding on aspects of working memory than some other types of phonological awareness task, but the ability to hold in mind and manipulate sounds must rely on verbal storage and working memory to some degree. Therefore any improvements to verbal short term memory and verbal working memory could contribute to improved performance on these tests.

Contrary to findings in Dahlin (2011), who did not find any improvements in decoding tasks after working memory training, children in the current study improved their nonword reading efficiency, evidenced by performance on the phonemic decoding TOWRE subtest, which is basically decoding at speed. Decoding nonwords for the phonemic decoding TOWRE subtest tasks the non-lexical route describe by the DRC Model (Coltheart, 2006); visual features of the nonword have to be analysed and phonological codes for pronouncing the word retrieved according to stored letter to sound conversion rules. Working memory training did not include any input relating to letter to sound conversion, but improvements to visuo-spatial or verbal working memory domains might impact on speed and efficiency of processing, leading to more words being spoken aloud in the 45 seconds allowed for the assessment.

According to Loosli et al. (2012), "transfer occurs if the training and transfer task share common processes." (p. 64). Other possible reasons why performance on decoding tasks improved could relate to teachers and parents targeting these skills alongside and after the working memory training, although these skills are constantly worked on, so perhaps improved working memory skills permitted more efficient learning of constantly practised, but hard to learn skills.

An examination of the individual assessment profiles in Appendix E shows that most participants, regardless of their glue ear status, had reasonably good phonological awareness to begin with. Only six children, Ryan, Victor, Jenna and Cheryl from the OME group, all in Years 4 to 6, and James and Colin, in Year 3, from the comparison group had initial phonological awareness scores below a standardised score of 100 to begin with. Perhaps the children's initial performances on these tasks were restricted by verbal short term and verbal working memory limitations rather than poor phonological awareness alone, and increases in capacity in these areas enabled them to achieve performances which more accurately reflected their phonological competence.

Improvements to sight word reading are more difficult to explain in terms of transfer effects from working memory training. Recognising previously unfamiliar words would rely on repeated exposure, but it is unclear how stronger working memory abilities might make it easier for children to recognise and speak aloud familiar words. It is possible that the children became faster at naming familiar words as a practice effect of repeated tests, but in terms of retrieval, these improvements were not a good fit with changes to rapid naming speeds, as only the comparison group achieved a significant improvement on this measure, between Times 2 and 3. Rapid naming scores for both groups had also been difficult to explain, as they were not correlated with other factors and seemingly not affected by working memory training, as shown by lack of any significant change between Times 1 and 2.

Holmes (2012) suggested that standardised tests, which are designed to be robust and therefore not particularly sensitive to small differences, might not be the right kind of assessment to use when looking for transfer effects. This might account for the paucity of transfer effects reported in the literature. Also, previous research did not include teacher feedback or individual intervention programmes designed to help the children catch up with concepts they had previously found it difficult to learn. As a teacher, I would not expect that any sudden improvement in a child's capacity to learn would automatically enable them to understand and manage concepts which had previously been impossible for them and on which they had fallen behind. Previous research using working memory training (Dunning, 2012) had indicated that any academic improvements occurred several months after training, as the children got used to working with their new capabilities, and began to make better progress in lessons. This better progress was evidenced by qualitative data, rather than quantitative standardised test results. The current study was conducted in my own school, with children who were known to me. This enabled me to discuss the meaning of findings from the pre- and post-training assessments with parents, teaching assistants and teachers, which might have assisted them to set specific learning targets, or succeeded in maintaining a focus on particular skills which might otherwise have been overlooked.

New studies are currently under way (Dunning, 2012; Holmes, 2012) which will attempt to identify the kind of explicit instruction necessary to help children make best use of their new working memory capacity. This daily dynamic decision making relating to identifying and planning activities to help children make appropriate and meaningful next steps is difficult to describe or set out as a procedure, but could account for the transfer effects in my study, which were less clear in previous randomised controlled trials (Dunning, 2012).

Learning identity and attitudes to learning

. It was not possible to find group differences in learning identity evidenced by survey results between OME and a typically developing comparison group, however, there were considerable differences between individuals within each group. As previously mentioned, identity is a problematic concept, and this study focused on narrow aspects of children's feelings and attitudes about themselves as learners. Changes in images of themselves as learners relating to Perceived Learning Capability, Preparedness for Learning and Response to the Curriculum may reflect whether or not children felt that working memory training had helped them, changes in degree of positivity towards statements reflecting motivation and level of perseverance and response to challenge, such as General Work Ethic, might indicate whether the new skills had made a difference to the children in class. Children's responses to Feelings about Self and School and Attitudes to Attendance could shed light on feelings of connectedness with the school community, revealed by their desire to be at school rather than elsewhere.

Training effects were analysed by examining the changing pattern of relationships between survey factors and AWMA between the beginning and end of the study, which might be useful to explore links between positive feelings and school success. Improvements to phonological processing and single word reading and decoding are also discussed, insofar as improved skills may result in greater self-regard, confidence and better relationships with teachers, as well as feelings that the curriculum might be a better fit to individual learning capabilities. After training, there were moderate links for the OME group for Response to the Curriculum and verbal short term memory (.64) and visuo-spatial WM (.63), and Attitudes to Teachers and verbal short term memory. There were no links between survey factors and AWMA measures for the comparison group after training. Therefore, for the OME group, stronger skills in verbal storage and visuo-spatial working memory were linked to greater agreement that the work set was a better match to their developed skills, and relationships with teachers improved as verbal storage increased.

The effects of working memory training on learning identity and attitudes to learning

While the difficulties experienced by some of the children in this study were relative, and may have resulted from unfair comparison with their high achieving peers and unrealistic parental expectations, it is clear that some aspects of the school experience at Bridgeworth School were painful for a few of the children, and that these painful feelings were connected with the problems they experienced with the curriculum, whether or not these problems were severe in real terms. Perhaps the competitive ethos at the school overrode the positive effects of gains from the working memory training. Expectations at Bridgeworth School were summed up by Niall, a new pupil in the comparison group, who when asked about the large decrease in his scores for feelings of safety and security at school, from the 100th to the 15th percentile, with smaller decreases in General Work Ethic, Learner Confidence, Attitudes to Attendance and Response to the Curriculum, all to below the 25th percentile, said,

> "*It's because then, I hadn't been long in the school, so I didn't really know, I expected… I expected to be happy, but then*…"

and continued,

> "*It's nothing really, just some things are changing, like they might be if I'm enjoying the work a lot, or not, 'cos sometimes it's really hard work. English … it just takes longer than when I do maths and I find it much harder. It's comprehension work.*"

These words were from a very able child with high initial scores in all assessments. If he found the work challenging, and it affected his feelings about school to such a large extent, it is not surprising that some of the lower achieving children were distressed by their experiences.

OME and comparison group children appeared to be equally positive or negative about school and learning experiences. This means that at the end of the academic year within which the training took place, improved working memory functions, together with other improvements detailed in the Results Chapter, did not appear to have improved children's sense of well-being, according to the pupil attitude to self and school means.

One possible reason for this, articulated by Cheryl from the OME group, is that, while she was fully aware that she had improved, these improvements were never enough. Every time she caught up and mastered a particular concept, new, more difficult ideas were introduced. This made her feel that she would never be good enough, although her high levels of determination and strong desire to fit in made it impossible for her to give up. She felt that other children did not need to work nearly as hard as her to achieve at a much higher level, and her feelings about herself became more negative.

As for Harold, his end of year Progress in English and Progress in Maths standardised scores were better than the previous year's scores, maths in particular showed an improvement, from deficit, to within the average range. Harold's AWMA scores showed strong improvements in all areas and continued improvements six months after training, although verbal short term memory remained a little below average. It is possible that this continuing weakness in verbal storage is the locus of his difficulty in listening to and following teacher demonstrations and explanations. Harold had become more positive on all survey factors apart from factor 6, General Work Ethic, which remained unchanged. His feelings of well-being, attitudes to attendance and attitudes to his teachers became very much more positive. Therefore for Harold, it is possible to say that the changes brought about by working memory training have had a positive effect on his feelings about himself as a learner, have made him happier to come to school and much more positive about his relationships with teachers, but have not reduced his overall levels of anxiety.

Survey profile changes shown by Emily, reflected considerable improvements in positive feelings following training. Despite a reluctance to admit to feeling any more positive during our conversations, survey results revealed a less negative outlook. Combined with improvements in end of year Progress in English and Progress in Maths standardised tests, this provided evidence for optimism.

As each child’s survey profile was so different, reacting to the unique contributions of personality, personal relationships within school, family and learning experiences, it is not possible to say that working memory training alone effected changes in children’s learning identity. Improvements to working memory capacity and stronger test results were not always viewed as successes; rather, there seemed to be a fixation on learner characteristics which were difficult to change, as Emily said, “*When I’m on the last second I’m only on the first question*,” so she focused on her speed, rather than her ability to understand the questions and get them right, which she mentioned later when talking about how much easier she found it to work through maths activities at home with her father.

Working memory training can reduce anxiety for children like Emily, however, for others, for example, Cheryl, understanding of the need to work much harder than their peers to maintain the same position in class continued to create anxiety that they might not be able to keep up.

Limitations, professional considerations and generalizability

This small-scale study was conducted within a non-selective independent school with high academic standards. The prevalence of OME-related hearing loss and consequent barriers to learning in children in this fairly exclusive school, may indicate that similar problems exist in other types of school, possibly masked by other difficulties. Therefore, although limited in terms of scale, this study has the potential to be highly informative.

In the current study, none of the teachers, including the Head Teacher, were aware of all the children’s OME status before the matter was raised during our conversations, because parents did not think that the matter was important enough to mention to teachers. School based learning depends very much on listening to the teacher, and listening to and following instructions depend on being able to hear, and then remember what has been said. This study has made an original contribution to existing knowledge about the links between OME and children’s working memory limitations, and the improvements to working memory following working memory training. A further contribution this study might make to improving children’s school experiences might be to suggest that parents are specifically asked about their children's previous OME status at school entry, which would enable the teacher to make reasonable adjustments to teaching strategies, which could be as simple as making changes to seating arrangements, to ensure that any adverse effects of OME related hearing loss for those children are minimised, or to begin phonological skills training interventions at an appropriate time.

In relation to the working memory training intervention, the size of the improvements to working memory, together with the 'normalisation' effects, where the group mean scores of the OME group were improved after training to the extent that they resembled pre-training scores of typically developing children, suggest that the training was worthwhile. If I were to repeat this study, the changes I would make would largely be in relation to selection and inclusion criteria for participants. This study was limited in this respect, as the participants represented an opportunity sample, due to the small numbers of children at the school. It was also limited in that, although I attempted to investigate the degree of severity of OME experienced by the children, parents' memories on the subject so many years later were not very reliable. Therefore the overlap between the hearing status of the OME group and comparison group participants during their early years cannot be rigorously determined.

Nevertheless, even with some blurring of group boundaries, clear differences between the groups indicate that further investigation of OME-related working memory deficits might be fruitful. In that case, participant recruitment at three years of age, when details of childhood illnesses might be more readily recalled, together with an observation of progress with language and literacy during Nursery, Reception and Year 1, might provide richer portraits of problems linked to OME. It would also be useful to combine the perspectives of teachers, speech and language therapists and audiologists, so that hearing levels can be sampled regularly, together with speech and language development and progress with school subjects, as in Bennet *et al.* (2001), but with the addition of the AWMA. The new edition of this test, reported to be available in 2014, which is less time consuming and difficult to administer, could be used at the beginning of Years 1 and 2, to determine whether children with OME were on a different development trajectory to their typically developing peers. If so, working memory training could be provided during the first term of Year 2, or even as part of a summer school programme prior to Year 2 entry. The AWMA could be repeated at the beginning of Year 3 to evaluate the impact of the intervention, and information about progress within Early Learning Goals and National Curriculum Assessment Focuses could be used to determine whether working memory training made any difference to children's achievement when measured against predictions made in Year 1.

If this research were to be conducted in a large primary school, or within a federation of schools, it would not be unreasonable to expect to recruit over 100 participants, which would increase the reliability of the results and statistical power of the data analysis. In this way, the problems associated with OME might be identified and addressed at an earlier stage, before poor progress could impact on children's self-image.

Overall conclusions

Working memory training improved the working memory capacities of children in both groups, but more so in the OME group, decreasing the differences between the groups to a point where they were no longer significant. However, the training did not impact on group differences in learning identity as shown by pupil attitudes to self and school survey scores. Individuals within each group reported changes to their feelings about themselves and school to a greater or lesser degree, with more positive changes dependent on improvements to maths and English performance and relationships with teachers.

This study has made a contribution to existing knowledge in relation to the links between OME and working memory limitations, in view of the clear differences between working memory capabilities of the children with and without a history of OME in the findings. It has also extended existing knowledge of the emotional characteristics of children with poor working memory related to OME in an academic context, by showing that OME group children with difficulties relating to English were emotionally vulnerable in terms of Self-regard, children with difficulties relating to maths, or a combination of maths and English, appeared to be more emotionally robust than those with difficulties in one curriculum area, but that overall, children with poor working memory linked with OME were not significantly more negative about themselves as learners than other children at the school.

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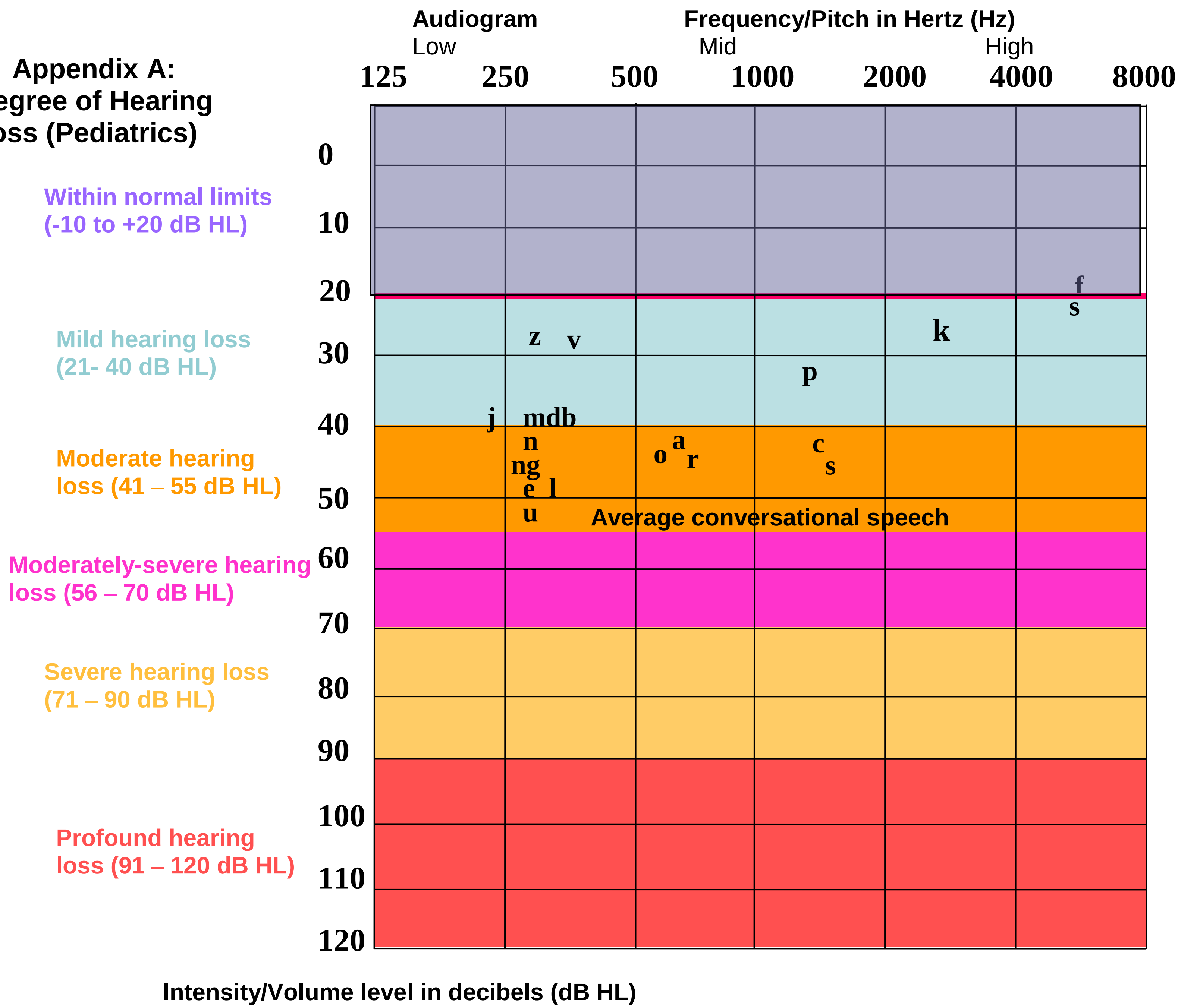
Appendix A: Degree of Hearing Loss (Pediatrics)



Appendix B. Interview prompts before and after working memory training.

All opening prompts were general, leaving the children free to select topics which were important to them. All children were known to the interviewer, and interviews were conducted after short assessment procedures, when rapport had already been established.

Before training:

Thank you for agreeing to help me to look for ways to help you, and other children, with your learning. Before you go, I wonder if you could help me by telling me what you think about just a few things connected to school and learning.

How are things going for you in your new class?
How do you feel about the work in class this year?
Is there anything in particular that you really like or dislike?
Do you have any worries or concerns about school this year?

After training:

Thank you for helping me with this extra work. I have just a few more things to ask. At the beginning of the year, back in September, we talked about how things were going for you in your new class, and how you felt about the work. Now that we are nearly at the end of the year, can you tell me if anything has changed for you?

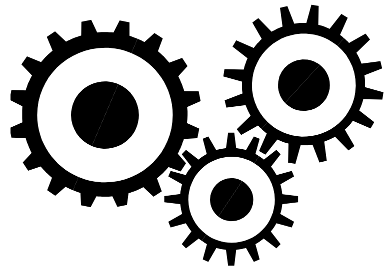
In September, you said that you were concerned about …, how do you feel about that now?

or

In September, you seemed to be really positive about …, could you tell me how you feel about … now?

Appendix C. Information Letter to Parents and Consent Form

ROBO RACER **Working memory Training**



Date:

Dear Parents,

Robo Racer Working Memory Training
I am delighted to be able to invite your child to join our new Robo Racer computer club next term. Rober Racers club runs every day, before school, during lunch break or after school, depending on your needs and commitments.

Membership of Robo Racer club entitles your child to 25 sessions using innovative working memory training software, Cogmed RM. Each session takes around thirty minutes and should be taken on consecutive weekdays. Cogmed RM memory training been shown to increase working memory capacity in the majority of users. Working memory restrictions can create barriers to learning, particularly in literacy and maths.

Improvements to working memory increase an individual's capacity to learn. Robo Racer activities are hard work but completion of the course should provide your child with a greater selection of tools to think with, enabling them to be better prepared to learn.

Parent Workshops
I will be running a series of Parent Workshops where you can try the programme yourselves, learn more about working memory and ask questions.

Permission Request
Robo Racer club forms part of an ongoing action research cycle at the school and I am currently interested in the links between working memory capacity and how children manage in the classroom. I am particularly interested in how difficulties with working memory might affect children's attitudes to aspects of their schooling and how parents feel about this. Membership of Robo Racer club is open to all pupils, however, I would very much appreciate your permission to include data relating to your child during the course of the intervention in a report which will form part of my thesis for a Doctorate in Education. The children will also be asked if they wish to participate at each stage of the study.

Assessments and Interviews
The information I would like to gather from the children relates to their attitudes and feelings about themselves and school and would be collected in the form of a survey administered on the computer together with a short individual interview at the beginning of the study, in September this year. I would also appreciate details of any problems with ear infections, 'glue ear' or hearing problems your child may have experienced before starting school. I would need to carry out a short working memory assessment and short assessments of phonological processing and reading efficiency. Other data concerning the children would be collected as part of lesson observations and talking to the teachers, which is part of our usual quality assurance programme. Assessments of phonological processing, reading efficiency and working memory would be repeated after the Robo Racer training and again at the end of the study, while the attitude survey and interview would be repeated in June next year.

Your views, thoughts and feelings are very important to me and if you would be willing to be interviewed privately, your contributions would make a valuable addition to the study.

Confidentiality and Security
Confidentiality is of the highest importance and you can be assured that any data collected relating to you and your children will be securely stored and personal details will be removed. Robo Racer club members will be issued with a unique password to access the training system, and no identifying details relating to the children will be held on the computer. Pseudonyms will be used for participants mentioned in the final report.

Your child can join the Robo Racer Club without participating in the study and if you initially agree to participate, you may withdraw your permission at a later date.

If you have any questions or would like to know more about the structure and contents of any of the proposed assessments, please call in to see me before or after school.

Best wishes,

Karen Faulds

Learning Support Coordinator

Consent Form

I ______________________________ (insert name) wish to enrol my child

______________________________ (insert name) in Robo Racer club.

Please state your preference by ticking one time slot for each day:

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8am to 8.40am					
1pm to 1.30pm					
3.40pm to 4.10pm					

Background Information

Please read the following statements and if they apply, provide information to the best of your recollection.

☐ My child has not had any ear infections.

☐ My child first experienced an ear infection at age __________

☐ My child had ________ (*insert number*) ear infections before 12 months which were mild / severe (*delete as appropriate*)

☐ My child had _________(*insert number*) ear infections between 12 and 24 months which were mild / severe (delete as appropriate)

☐ My child had _________ (*insert number*) ear infections after 24 months which were mild / severe (*delete as appropriate*)

☐ My child has had grommets inserted (*please insert date*) ___________

☐ My child has had speech and language therapy (*please show dates*) ____

I give / do not give (*delete as appropriate*) permission for my child to participate in the research project outlined above.

Signed :____________________________ Date: ___________

Appendix D. Individual Assessment Scores

OME Group Individual Pre-training AWMA Scores

Name	*M/F*	*Year*	*V STM*	*V WM*	*VS STM*	*VS WM*
Mark	M	3	110	99	118	115
Melvin	M	3	103	91	130	109
Gerry	M	3	114	109	111	96
Ryan	M	6	80	93	113	89
Harold	M	3	80	72	80	76
Nathan	M	6	96	99	98	113
Victor	M	6	86	86	122	101
Brad	M	4	99	89	113	101
Tyler	M	5	105	82	98	116
Lucy	F	3	110	104	126	102
Emily	F	3	93	109	103	105
Sally	F	3	96	106	94	110
Leah	F	3	86	94	110	130
Jenna	F	4	137	112	117	98
Cheryl	F	4	72	85	102	84
Angel	F	6	107	82	76	97

OME Group Individual Post-training AWMA Scores

Name	*M/F*	*Year*	*V STM*	*V WM*	*VS STM*	*VS WM*
Mark	M	3	115	109	130	134
Melvin	M	3	114	114	130	128
Gerry	M	3	124	118	122	125
Ryan	M	6	106	107	119	96
Harold	M	3	80	89	117	95
Nathan	M	6	112	132	123	132
Victor	M	6	104	103	115	102
Brad	M	4	108	102	136	102
Tyler	M	5	128	108	132	116
Lucy	F	3	120	118	130	121
Emily	F	3	114	123	130	102
Sally	F	3	99	108	120	125
Leah	F	3	120	118	118	130
Jenna	F	4	137	99	128	107
Cheryl	F	4	90	102	115	107
Angel	F	6	109	88	107	102

OME Group Individual Six Month Post-training AWMA Scores

Name	*M/F*	*Year*	*V STM*	*V WM*	*VS STM*	*VS WM*
Mark	M	3	120	123	130	137
Melvin	M	3	133	127	147	128
Gerry	M	3	137	123	128	131
Ryan	M	6	109	116	113	110
Harold	M	3	96	108	119	113
Nathan	M	6	112	127	123	135
Victor	M	6	84	127	126	122
Brad	M	4	86	102	129	107
Tyler	M	5	136	98	134	135
Lucy	F	3	137	108	139	113
Emily	F	3	113	112	139	131
Sally	F	3	137	112	120	137
Leah	F	3	121	121	147	128
Jenna	F	4	137	112	143	116
Cheryl	F	4	108	102	125	124
Angel	F	6	88	74	99	97

Comparison Group Pre-training AWMA Scores

Name	*M/F*	*Year*	*V STM*	*V WM*	*VS STM*	*VS WM*
Niall	M	3	124	118	130	128
James	M	3	114	118	130	118
Fred	M	3	110	118	130	121
Colin	M	3	117	99	122	121
Leon	M	5	82	86	91	91
Melody	F	3	107	95	107	109
Ellie	F	5	101	98	132	110
Jess	F	3	124	123	99	115
Amelia	F	3	124	123	130	115
Kathy	F	3	99	132	130	125
Nat	F	3	117	91	130	112
Mandy	F	3	124	99	118	118

Comparison Group Post-training AWMA Scores

Name	*M/F*	*Year*	*V STM*	*V WM*	*VS STM*	*VS WM*
Niall	M	3	124	127	130	121
James	M	3	117	108	147	116
Fred	M	3	104	112	147	119
Colin	M	3	117	99	122	118
Leon	M	5	90	102	119	113
Melody	F	3	117	114	126	125
Ellie	F	5	108	102	136	129
Jess	F	3	137	131	139	131
Amelia	F	3	117	132	130	137
Kathy	F	3	117	116	147	137
Nat	F	3	117	123	132	121
Mandy	F	3	124	132	130	137

Comparison Group Six Month Post-training AWMA Scores

Name	*M/F*	*Year*	*V STM*	*V WM*	*VS STM*	*VS WM*
Niall	M	3	137	131	147	128
James	M	3	117	121	139	113
Fred	M	3	113	108	135	123
Colin	M	3	117	118	126	128
Leon	M	5	109	116	113	110
Melody	F	3	117	93	139	113
Ellie	F	5	108	103	132	135
Jess	F	3	137	131	117	128
Amelia	F	3	117	132	130	121
Kathy	F	3	92	131	147	113
Nat	F	3	137	112	139	134
Mandy	F	3	137	120	147	134

OME Group Individual Pre-training CTOPP Scores

Name	*M/F*	*Year*	*Phonological Awareness*	*Phonological Memory*	*Rapid Naming*
Mark	M	3	97	97	97
Melvin	M	3	103	103	88
Gerry	M	3	130	106	106
Ryan	M	6	88	82	100
Harold	M	3	106	88	103
Nathan	M	6	112	97	103
Victor	M	6	100	97	97
Brad	M	4	103	91	112
Tyler	M	5	106	97	94
Lucy	F	3	103	103	106
Emily	F	3	103	88	112
Sally	F	3	115	88	100
Leah	F	3	100	88	127
Jenna	F	4	97	124	103
Cheryl	F	4	94	88	121
Angel	F	6	106	94	88

OME Group Individual Post-training CTOPP Scores

Name	*M/F*	*Year*	*Phonological Awareness*	*Phonological Memory*	*Rapid Naming*
Mark	M	3	112	103	100
Melvin	M	3	103	103	115
Gerry	M	3	127	112	115
Ryan	M	6	94	91	94
Harold	M	3	118	91	112
Nathan	M	6	124	97	91
Victor	M	6	109	94	103
Brad	M	4	124	93	109
Tyler	M	5	124	118	100
Lucy	F	3	127	118	115
Emily	F	3	123	100	100
Sally	F	3	115	103	103
Leah	F	3	127	97	118
Jenna	F	4	121	133	112
Cheryl	F	4	94	94	106
Angel	F	6	109	100	109

OME Group Individual Six Month Post-training CTOPP Scores

Name	*M/F*	*Year*	*Phonological Awareness*	*Phonological Memory*	*Rapid Naming*
Mark	M	3	130	109	97
Melvin	M	3	115	106	109
Gerry	M	3	132	121	112
Ryan	M	6	91	91	94
Harold	M	3	127	91	109
Nathan	M	6	127	106	100
Victor	M	6	127	85	100
Brad	M	4	121	85	112
Tyler	M	5	124	109	106
Lucy	F	3	136	121	115
Emily	F	3	127	100	94
Sally	F	3	130	112	100
Leah	F	3	121	100	109
Jenna	F	4	124	118	118
Cheryl	F	4	118	100	112
Angel	F	6	115	94	85

Comparison Group Pre-training CTOPP Scores

Name	*M/F*	*Year*	*Phonological Awareness*	*Phonological Memory*	*Rapid Naming*
Niall	M	3	112	127	112
James	M	3	91	106	100
Fred	M	3	127	103	106
Colin	M	3	97	97	124
Leon	M	5	103	85	97
Melody	F	3	118	91	91
Ellie	F	5	106	94	97
Jess	F	3	118	112	97
Amelia	F	3	121	109	106
Kathy	F	3	133	106	103
Nat	F	3	112	112	103
Mandy	F	3	121	106	112

Comparison Group Post-training CTOPP Scores

Name	*M/F*	*Year*	*Phonological Awareness*	*Phonological Memory*	*Rapid Naming*
Niall	M	3	130	139	127
James	M	3	91	100	100
Fred	M	3	130	100	100
Colin	M	3	109	106	115
Leon	M	5	121	103	91
Melody	F	3	139	112	97
Ellie	F	5	121	103	91
Jess	F	3	133	107	91
Amelia	F	3	130	106	109
Kathy	F	3	136	118	100
Nat	F	3	133	118	106
Mandy	F	3	145	112	112

Comparison Group Six Month Post-training CTOPP Scores

Name	*M/F*	*Year*	*Phonological Awareness*	*Phonological Memory*	*Rapid Naming*
Niall	M	3	125	127	124
James	M	3	127	112	115
Fred	M	3	124	109	121
Colin	M	3	121	103	118
Leon	M	5	127	103	106
Melody	F	3	133	100	94
Ellie	F	5	118	103	94
Jess	F	3	136	130	100
Amelia	F	3	136	124	127
Kathy	F	3	130	112	109
Nat	F	3	133	118	106
Mandy	F	3	133	124	112

OME Group Individual Pre-training TOWRE Scores

Name	*M/F*	*Year*	*Sight Word Reading Efficiency*	*Non-word Reading Efficiency*	*Total Word Reading Efficiency*
Mark	M	3	100	85	91
Melvin	M	3	100	95	97
Gerry	M	3	117	116	120
Ryan	M	6	95	85	88
Harold	M	3	102	99	101
Nathan	M	6	99	100	99
Victor	M	6	103	105	103
Brad	M	4	106	95	101
Tyler	M	5	108	96	102
Lucy	F	3	108	108	108
Emily	F	3	120	116	122
Sally	F	3	117	103	112
Leah	F	3	123	110	120
Jenna	F	4	130	121	131
Cheryl	F	4	105	95	100
Angel	F	6	104	93	98

OME Group Individual Post-training TOWRE Scores

Name	*M/F*	*Year*	*Sight Word Reading Efficiency*	*Non-word Reading Efficiency*	*Total Word Reading Efficiency*
Mark	M	3	110	110	112
Melvin	M	3	123	112	115
Gerry	M	3	121	122	126
Ryan	M	6	95	97	95
Harold	M	3	107	98	103
Nathan	M	6	103	103	104
Victor	M	6	107	110	110
Brad	M	4	100	119	111
Tyler	M	5	110	96	104
Lucy	F	3	126	117	126
Emily	F	3	124	114	122
Sally	F	3	111	104	109
Leah	F	3	120	125	127
Jenna	F	4	122	125	128
Cheryl	F	4	106	94	100
Angel	F	6	109	107	110

OME Group Individual Six Month Post-training TOWRE Scores

Name	*M/F*	*Year*	*Sight Word Reading Efficiency*	*Non-word Reading Efficiency*	*Total Word Reading Efficiency*
Mark	M	3	108	95	102
Melvin	M	3	113	122	121
Gerry	M	3	118	127	124
Ryan	M	6	103	103	104
Harold	M	3	110	108	111
Nathan	M	6	117	115	119
Victor	M	6	107	104	107
Brad	M	4	115	117	119
Tyler	M	5	116	98	108
Lucy	F	3	129	127	131
Emily	F	3	121	109	118
Sally	F	3	117	115	119
Leah	F	3	119	106	115
Jenna	F	4	128	113	125
Cheryl	F	4	112	97	105
Angel	F	6	109	107	110

Comparison Group Pre-training TOWRE Scores

Name	*M/F*	*Year*	*Sight Word Reading Efficiency*	*Non-word Reading Efficiency*	*Total Word Reading Efficiency*
Niall	M	3	109	135	126
James	M	3	105	98	102
Fred	M	3	118	119	121
Colin	M	3	112	104	110
Leon	M	5	108	103	107
Melody	F	3	99	100	99
Ellie	F	5	106	98	102
Jess	F	3	108	108	108
Amelia	F	3	123	122	127
Kathy	F	3	130	130	136
Nat	F	3	117	103	112
Mandy	F	3	118	122	124

Comparison Group Post-training TOWRE Scores

Name	*M/F*	*Year*	*Sight Word Reading Efficiency*	*Non-word Reading Efficiency*	*Total Word Reading Efficiency*
Niall	M	3	126	141	140
James	M	3	107	92	102
Fred	M	3	112	119	119
Colin	M	3	117	106	114
Leon	M	5	104	96	100
Melody	F	3	99	100	99
Ellie	F	5	109	114	114
Jess	F	3	112	106	111
Amelia	F	3	127	127	132
Kathy	F	3	132	134	140
Nat	F	3	120	118	123
Mandy	F	3	124	119	126

Comparison Group Six Month Post-training TOWRE Scores

Name	*M/F*	*Year*	*Sight Word Reading Efficiency*	*Non-word Reading Efficiency*	*Total Word Reading Efficiency*
Niall	M	3	132	139	143
James	M	3	114	114	117
Fred	M	3	121	128	129
Colin	M	3	124	108	119
Leon	M	5	108	108	108
Melody	F	3	104	103	107
Ellie	F	5	105	117	113
Jess	F	3	114	104	111
Amelia	F	3	127	127	132
Kathy	F	3	132	139	143
Nat	F	3	118	110	117
Mandy	F	3	118	109	116

OME Group Individual Pre-training PASS Scores (Percentages)

Name	*M/ F*	*Year*	*1 FAS*	*2 PLC*	*3 SR*	*4 PFL*	*5 ATT*	*6 GWE*	*7 LC*	*8 ATA*	*9 RTC*
Mark	M	3	24.3	9	14	17.7	12.2	1.1	22.9	19.6	47.6
Melvin	M	3	100	85.9	1.3	100	100	23.1	100	51	1.5
Gerry	M	3	39.1	33.2	72.3	44.4	43.3	75.3	8.6	26.6	97.8
Ryan	M	6	65.3	30.7	42.3	45.8	73.2	79	72.1	73.3	83.2
Harold	M	3	15.5	26.1	44.8	24.6	12.2	56.5	33.7	36.3	36.6
Nathan	M	6	100	95.4	84	85.7	35.5	60.3	76.8	100	82.5
Victor	M	6	71.6	10.4	8.3	61.9	20.9	3.6	13.2	55.8	15.7
Brad	M	4	10.4	77.3	43.4	30.1	27.4	57.8	41.4	32.5	32.8
Tyler	M	5	100	47.4	15.8	70.7	73.2	79	85	61.9	41.6
Lucy	F	3	63.8	50.3	63.3	57.5	69.2	39.2	22.9	19.6	47.2
Emily	F	3	10.1	2.9	6.4	12.7	1.8	4.5	6.9	14	18.4
Sally	F	3	3.8	20.3	63.4	57.5	24.6	75.3	22.9	26.6	72.3
Leah	F	3	39.1	12	44.8	24.6	12.2	23.1	18.6	36.3	36.6
Jenna	F	4	71.8	32.4	43.3	65.5	46.9	57.8	34.6	68.8	83.3
Cheryl	F	4	71.3	19.4	74.1	40.4	46.9	39	41.4	68.8	72
Angel	F	6	100	33.7	64.8	85.7	100	38.3	60.5	90	82.5

OME Group Individual Six Month Post-training PASS Scores (Percentages)

Name	*M/ F*	*Year*	*1 FAS*	*2 PLC*	*3 SR*	*4 PFL*	*5 ATT*	*6 GWE*	*7 LC*	*8 ATA*	*9 RTC*
Mark	M	3	12.5	15.6	35.4	17.7	43.3	23.1	11.8	10.3	36.6
Melvin	M	3	49.8	32.2	54.3	44.4	69.2	56.5	22.9	51	60.8
Gerry	M	3	15.5	32.2	35.4	24.6	43.3	87.8	22.9	36.3	47.6
Ryan	M	6	100	82.5	23.1	83.3	100	39.5	72.3	73.2	11.6
Harold	M	3	63.8	33.2	44.8	44.4	43.2	56.5	47.4	78.6	47.6
Nathan	M	6	28.4	98.3	98.4	85.7	20.9	93.1	100	67.5	97.2
Victor	M	6	28.4	19.4	20.3	29.8	20.4	80.4	36	28.7	15.7
Brad	M	4	16.1	85.5	2.7	22.2	4.7	4.6	48.8	12.2	5.6
Tyler	M	5	65.3	56.5	42.3	57.8	48.8	60.2	72.2	73.5	56.5
Lucy	F	3	49.8	6.8	9.8	24.6	69.2	56.5	22.9	26.6	36.6
Emily	F	3	30.3	6.8	6.4	33.5	43.3	23.1	5	19.6	36.6
Sally	F	3	63.8	59.5	35.4	44.4	43.3	75.3	86.6	51	82.5
Leah	F	3	63.8	78.2	35.4	71.5	69.2	56.5	63.7	100	47.6
Jenna	F	4	100	19.4	82.4	65.5	72	39	41.4	83.7	72
Cheryl	F	4	16.1	25.3	17.6	30.1	14.5	10.1	23.4	16.8	32.8
Angel	F	6	100	1.4	20.3	29.8	20.9	80.4	36	28.7	15.7

Comparison Group Individual Pre-training PASS Scores (Percentages)

Name	*M/F*	*Year*	*1 FAS*	*2 PLC*	*3 SR*	*4 PFL*	*5 ATT*	*6 GWE*	*7 LC*	*8 ATA*	*9 RTC*
Niall	M	3	100	59.5	14	57.5	100	39.2	27.8	36.3	36.3
James	M	3	49.8	50.3	92.2	86.1	43.3	9.6	63.7	63	93.3
Fred	M	3	63.8	41.3	27.2	86.1	69.2	100	33.7	78.6	36.6
Colin	M	3	49.8	59.5	44.8	86.1	69.2	39.2	22.9	63	82.5
Leon	M	5	65.3	7.3	4.1	13.4	17.2	9.8	3.2	49.2	11.6
Melody	F	3	100	68.9	27.2	57.5	100	75.3	22.9	36.3	60.8
Ellie	F	5	54.4	30.7	65.1	45.8	8.9	21.7	48	61.9	56.5
Jess	F	3	24.3	33.2	9.8	71.5	69.2	23.1	27.8	36.3	18.4
Amelia	F	3	39.1	59.5	44.8	12.7	24.6	9.6	55.8	78.6	47.6
Kathy	F	3	63.8	68.9	44.8	44.4	24.6	23.1	71.7	26.6	60.8
Nat	F	3	100	41.3	92.7	57.5	24.6	56.5	71.7	63	72.3
Mandy	F	3	100	15.5	20.2	71.5	43.3	87.8	11.8	51	72.3

Comparison Group Individual Six Month Post-training PASS Scores (Percentages)

Name	*Sex*	*Y*	*1 FAS*	*2 PLC*	*3 SR*	*4 PFL*	*5 ATT*	*6 GWE*	*7 LC*	*8 ATA*	*9 RTC*
Niall	M	3	15.5	68.9	44.8	57.5	100	23.1	22.9	19.6	18.4
James	M	3	39.1	85.9	96.3	33.5	43.3	75.5	47.4	63	82.5
Fred	M	3	39.1	59.5	72.3	71.5	69.2	56.5	55.8	51	47.6
Colin	M	3	19.4	59.5	44.8	44.4	24.6	23.1	40.1	19.6	36.6
Leon	M	5	16.1	25.3	64.2	40.4	46.9	89.9	18.8	12.2	44.7
Melody	F	3	100	68.4	54.3	57.5	69.2	87.8	27.8	100	60.8
Ellie	F	5	65.3	82.5	94.9	70.7	8.9	4.2	72.2	87	83.2
Jess	F	3	63.8	59.5	20.2	33.5	43.3	56.5	71.7	51	60.8
Amelia	F	3	63.8	41.3	44.8	12.7	24.6	56.5	55.8	78.6	60.8
Kathy	F	3	30.3	59.5	44.8	44.4	100	56.5	55.8	26.6	36.6
Nat	F	3	49.8	50.3	44.8	57.5	43.3	23.1	40.1	63	36.6
Mandy	F	3	19.4	5.2	80.3	35.5	6.2	75.3	11.8	19.6	82.5

OME Group Individual English and Maths and Raven's SPM scores 2011/12

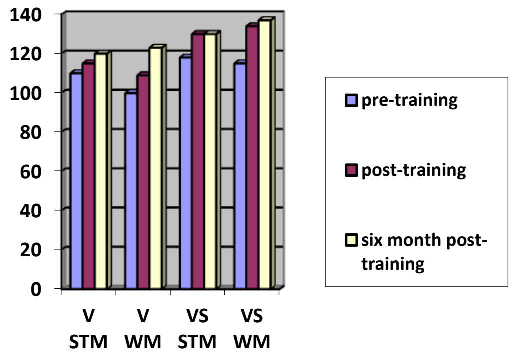
Name	*M/F*	*Year*	*English 2011*	*English 2012*	*Maths 2011*	*Maths 2012*	*Raven's SPM Percentile band*
Mark	M	3	100	86	102	103	5 -10 low
Melvin	M	3	82	101	101	113	50 – 75 high
Gerry	M	3	114	111	113	105	50
Ryan	M	6	96	105	97	103	75 – 90 low
Harold	M	3	88	90	77	86	25 – 50 low
Nicky	M	6	119	120	115	125	Above 95
Will	M	6	94	103	106	115	75 – 90 low
Brad	M	4	91	88	102	88	25 – 50 high
Tyler	M	5	115	113	108	109	75 – 90 low
Lucy	F	3	109	113	107	107	50 – 75 high
Emily	F	3	117	118	104	113	50 – 75 low
Sally	F	3	90	96	106	109	50 – 75 high
Leah	F	3	90	96	106	109	Above 95
Jenny	F	4	113	132	122	115	90 – 95 low
Cheryl	F	4	91	100	83	85	50 – 75 high
Angel	F	6	88	96	86	91	25 – 50 low

Comparison Group Individual English and Maths and Raven's SPM scores 2011/12

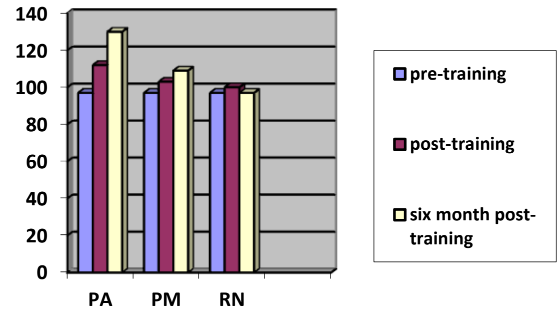
Name	*M/F*	*Year*	*English 2011*	*English 2012*	*Maths 2011*	*Maths 2012*	*Raven's SPM percentile band*
Niall	M	3	101	117	105	110	50 - 75 high
James	M	3	101	97	105	103	50 - 75 high
Fred	M	3	110	120	110	117	50
Colin	M	3	101	107	110	117	25 - 50 high
Leon	M	5	113	115	108	109	25 - 50 high
Melody	F	3	97	93	85	87	25 - 50 high
Ellie	F	5	109	115	107	109	50
Jess	F	3	102	103	109	112	25 - 50 low
Amelia	F	3	114	116	107	118	75 - 90 high
Kathy	F	3	105	118	132	122	75 - 90 high
Nat	F	3	113	105	112	113	75 - 90 high
Mandy	F	3	119	118	108	127	50 - 75 high

Appendix E OME and Comparison Group Individual Profiles

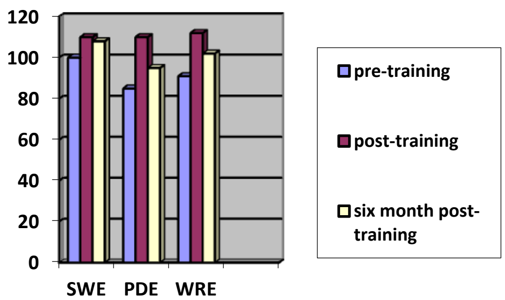
Mark | Year 3 | Male



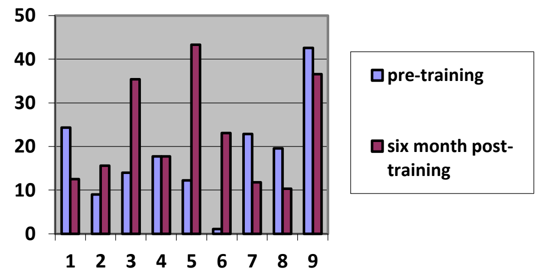
AWMA



CTOPP



TOWRE



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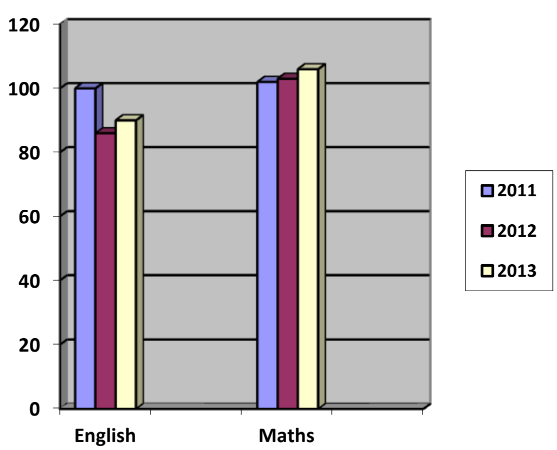


PiE and PiM

Brief History

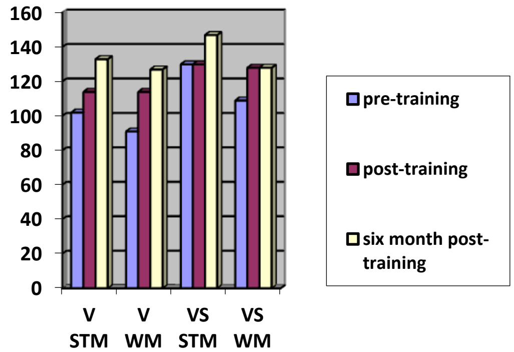
Several episodes of OME in pre-school years

Mark was very young in this year group, described by his teachers as a slow learner, steadily achieving at the lower end of the average range in tests and was a very slow worker in class. He had mild ear infections before starting school. Mark also had hypermobile finger joints which made it difficult for him to hold a pencil effectively and impeded his writing development.

Mark received early morning support two mornings a week during the Spring term in Year 2, using Read Write Inc (RWI) (Miskin, 2006) materials to support core activities.

Mark's parents were very supportive. In Year 2 they observed several one to one teaching sessions before school to learn how to use optimal literacy instruction methods and encourage Mark to transfer improving phonological awareness and phonemic skills to writing composition.

Melvin Year 3 Male



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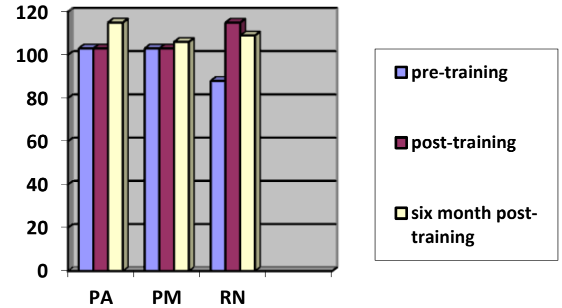

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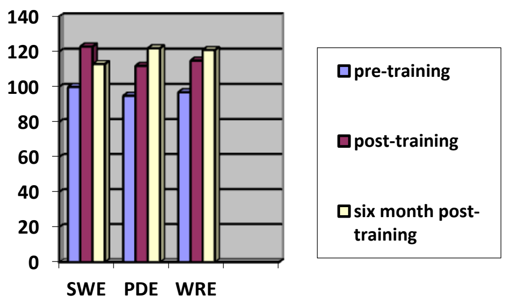

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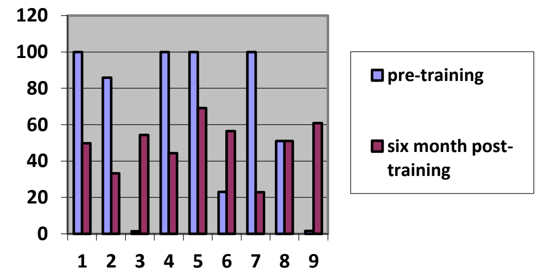

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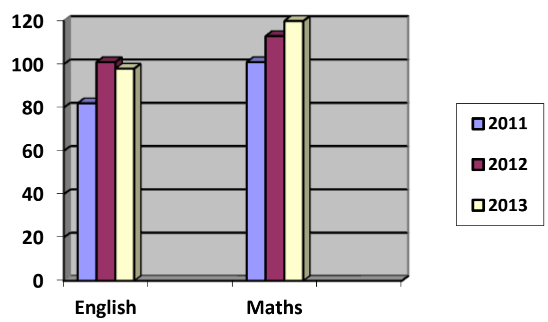


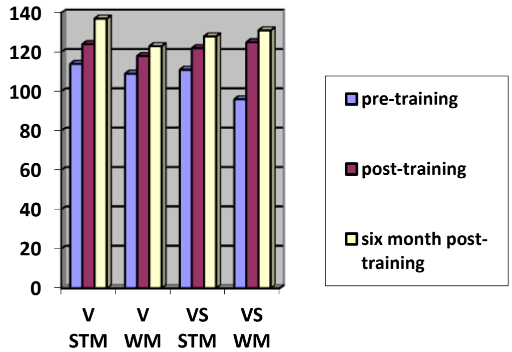
PiE and PiM

Brief History

One episode of OME in infancy

Melvin found it hard to learn his letters and sounds and was slow to develop an awareness of rhyme. He did not begin to blend and segment words until Year 1, and was slow to develop a useful sight vocabulary. His mother reported that she struggled with literacy and maths at school.

Gerry | Year 3 | Male



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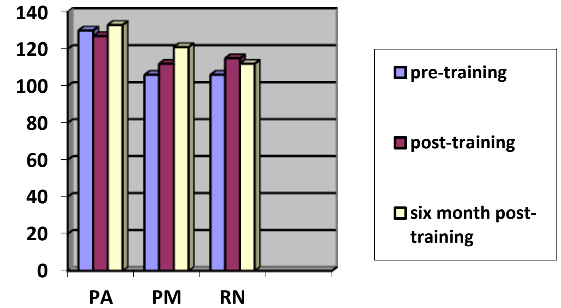

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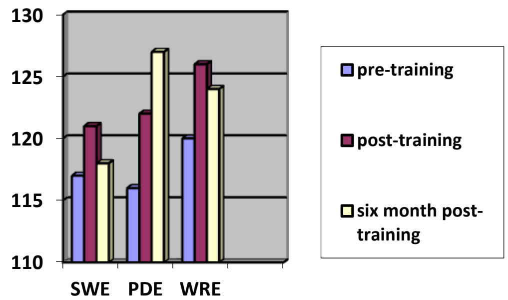

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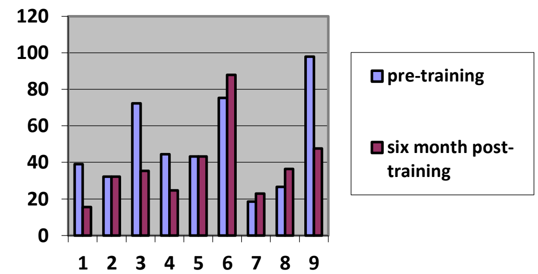

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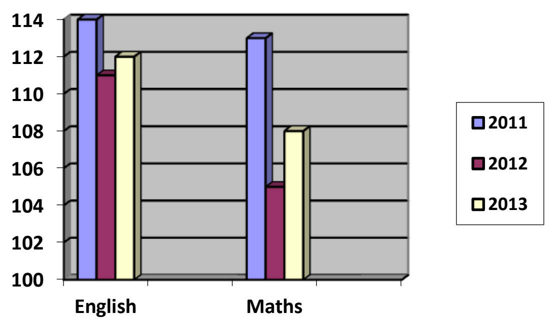


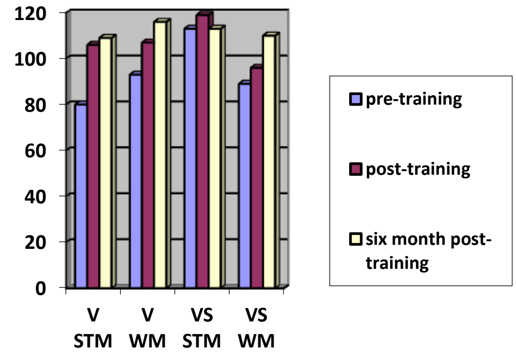
PiE and PiM

Brief History

Two or three episodes of OME during pre-school years

He was slow to learn to read and link letters to sounds. He achieved average scores in school assessments throughout Years 1 and 2. At the beginning of Year 3 he complained about finding the work difficult, but teachers reported that he was making satisfactory progress. Parents have not been concerned about his progress at any time.

Ryan Year 6 Male



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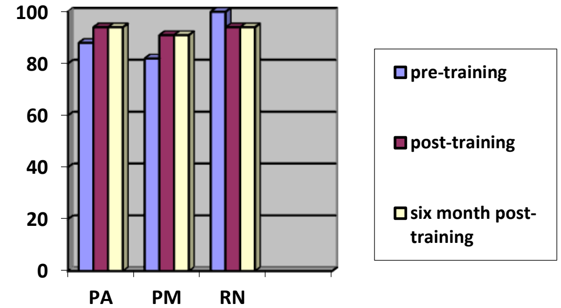

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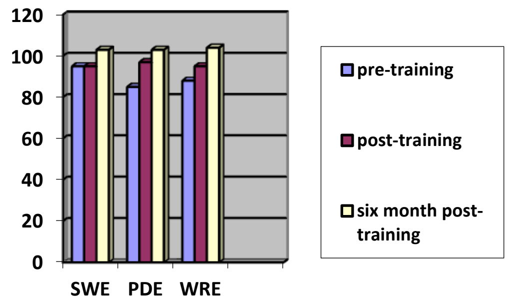

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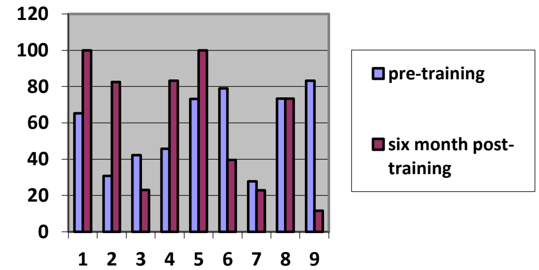

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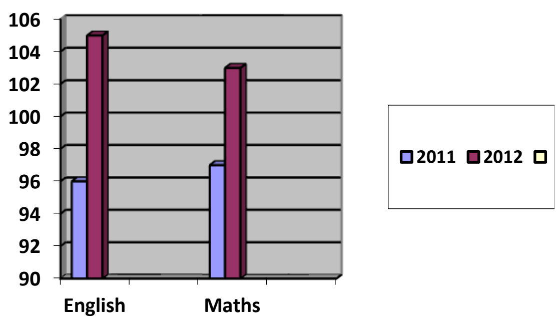


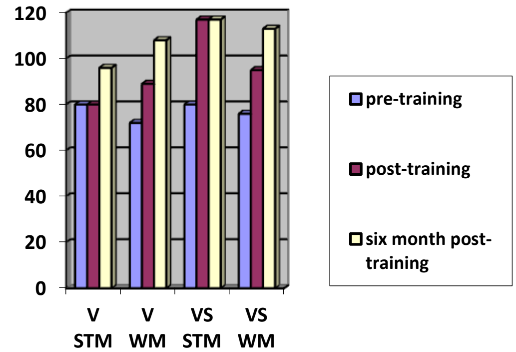
PiE and PiM

Brief History

Several episodes of OME during pre-school years

Referred by his teacher for extra support in maths during year 2, he had weaknesses in phonological awareness, reading and spelling compared to his peers. Ryan was able to learn multiplication tables and calculation algorithms, but found it difficult to switch between strategies, becoming unsure of the methods he should employ. Ryan was unsuccessful in secondary school selection tests in September 2011.

Harold Year 3 Male



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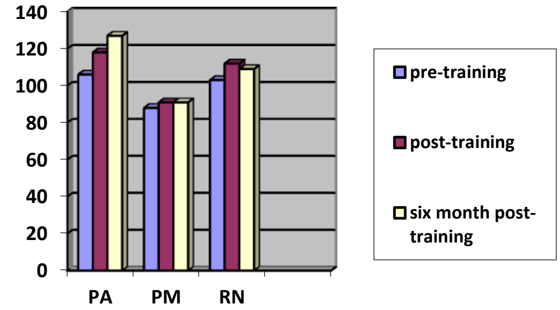

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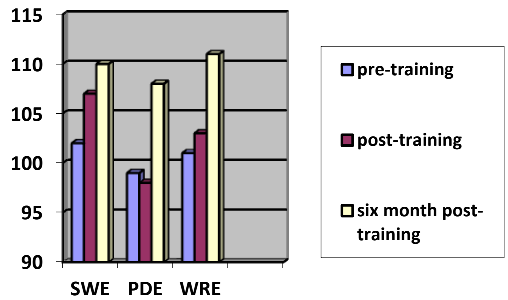

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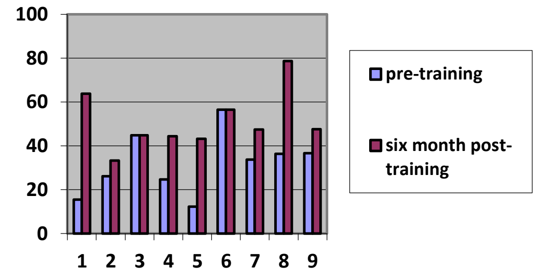

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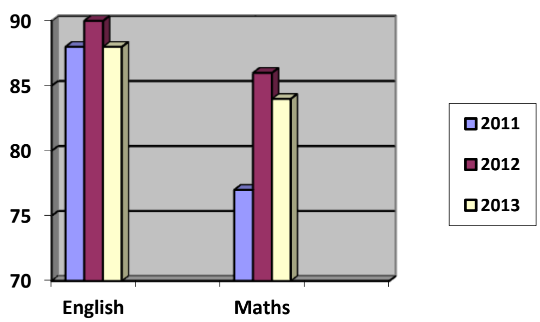


PiE and PiM

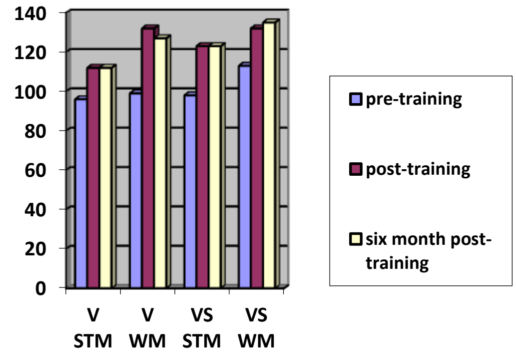
Brief History

Persistent OME from infancy, throughout pre-school and early years

Harold was the catalyst for this study, known to me from age three. He was prone to severe ear infections as a baby and during the pre-school years. He had a younger sibling who also suffered from persistent and severe ear infections in both ears caused by different bacterial strains which have so far been resistant to antibiotic treatment.

Harold’s mother reported some difficulties learning maths and English at school. His parents were very supportive and participated in a great deal of extra help, both before and after school, while his teachers did not always understand the amount of extra work Harold undertook to maintain his position at the bottom of the class.

Nathan Year 6 Male



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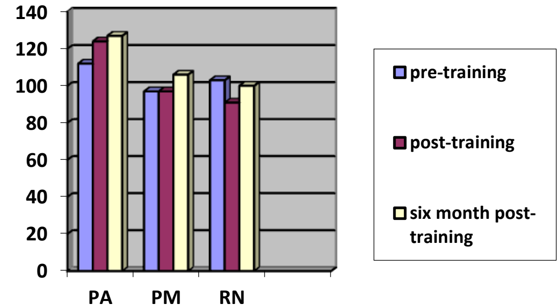

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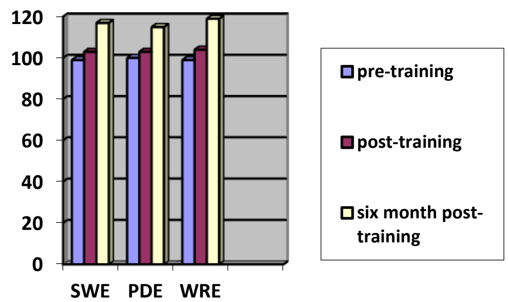

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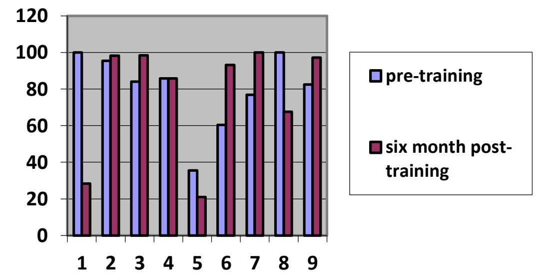

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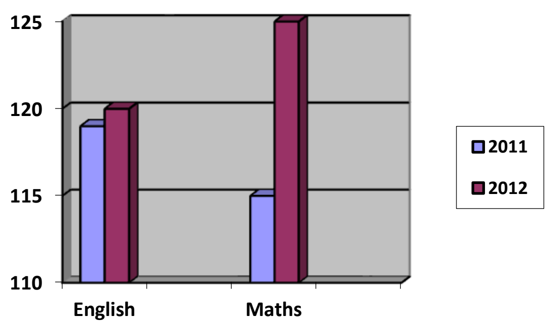


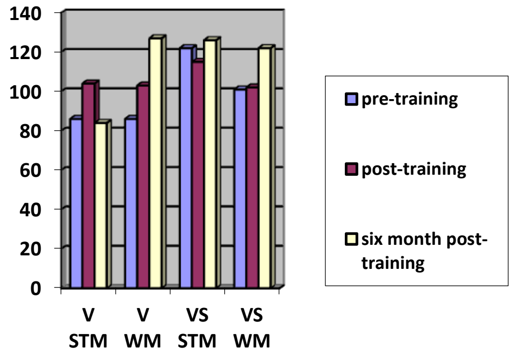
PiE and PiM

Brief History

Several persistent episodes of bilateral OME during infancy

Nathan had been referred for speech therapy before starting school but by the time he started school at age three, his language skills were very much above average. He presented as a clumsy, physically awkward child. In my Reception class, he was an avid reader of texts well beyond his age, who found it hard to hold a pencil, form letters correctly, and had poor fine motor control. Referral to an Occupational Therapist, revealed that he had hypermobile joints, particularly his fingers, which were causing problems, including fatigue and constant pain. Nathan did well in school tests, but read and wrote very slowly, so sometimes needed extra time. Nathan was successful in the secondary school selection tests in September 2011

Victor Year 6 Male



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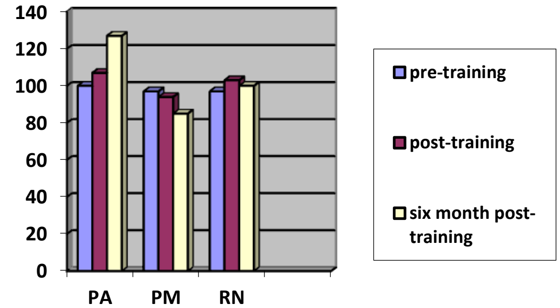

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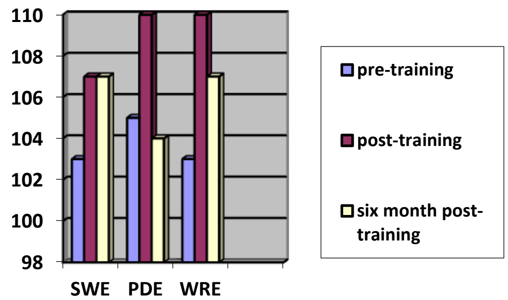

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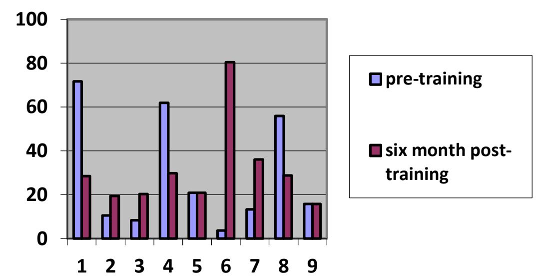

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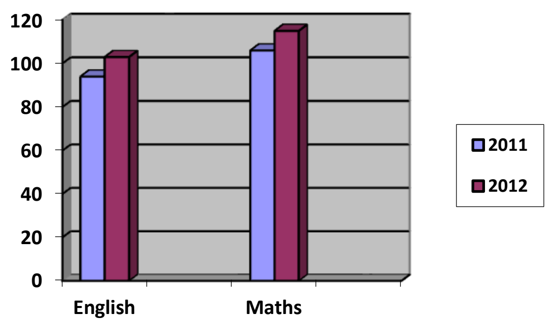


PiE and PiM

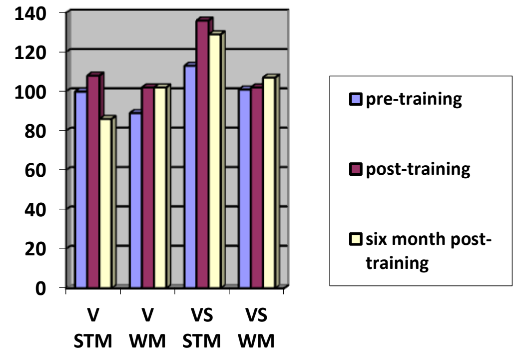
Brief History

Several episodes of OME from infancy throughout early childhood

Victor presented in reception with a blank expression a runny nose. He often became upset, did not enjoy school and became particularly anxious about tests and was fearful about calling out his weekly spelling and mental maths scores in class.

Victor did not enjoy reading or writing, but had been attaining well within the average range for English tests and above average for maths during the junior primary years. Victor was successful in the secondary school selection tests in September 2011

Brad Year 4 Male



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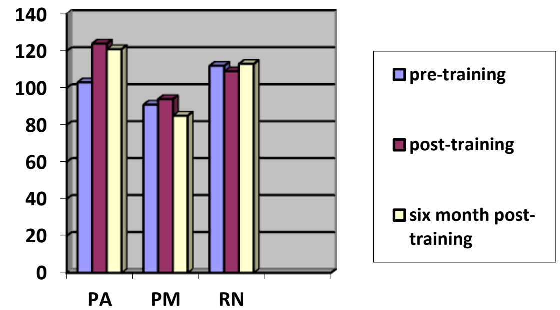

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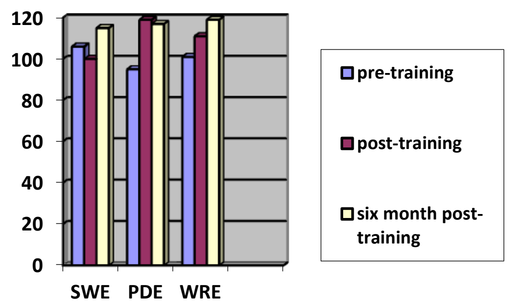

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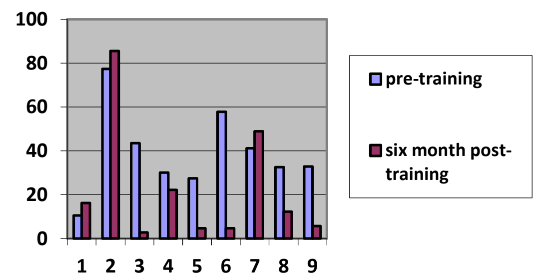

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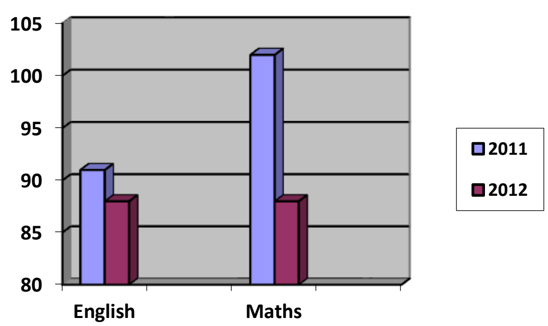


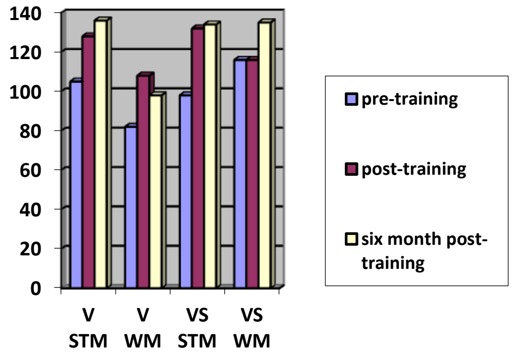
PiE and PiM

Brief History

One or two episodes of OME during pre-school years

A low achiever with, according to his teachers, some disposition and attitude issues, as well as attention, concentration and listening problems in class and in games lessons. He achieved at the lower end of the average range in school tests throughout Years 1 to 4. Brad was unsuccessful in secondary school selection tests in September 2013.

Tyler Year 5 Male



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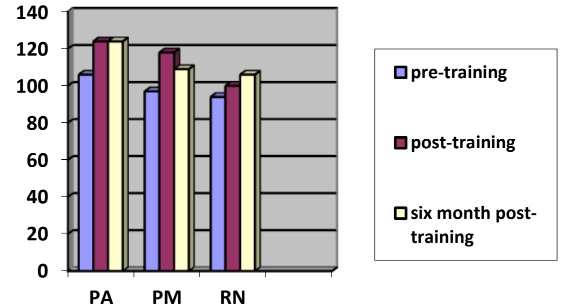

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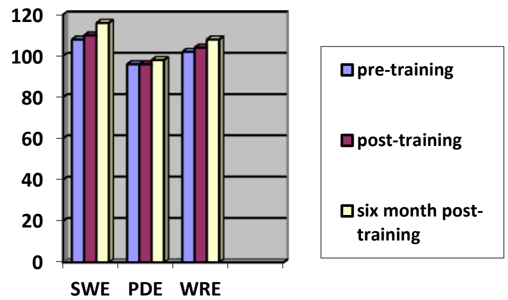

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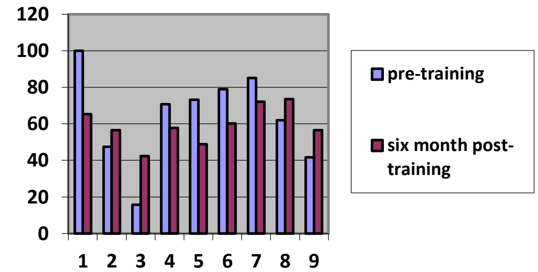

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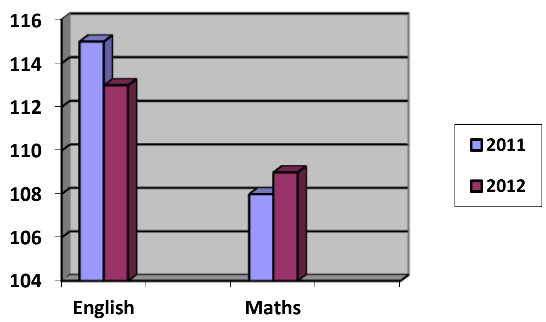


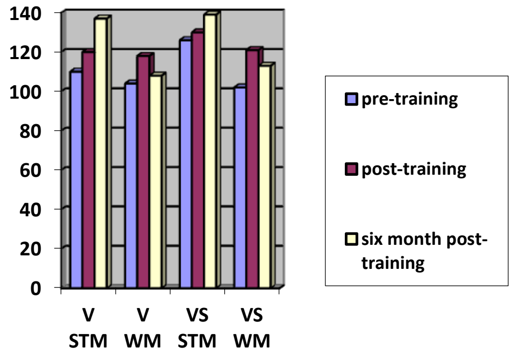
PiE and PiM

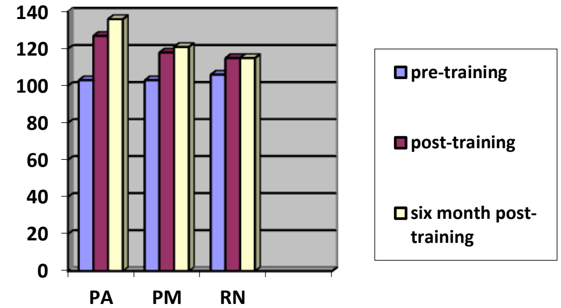
Brief History

Several episodes of OME during pre-school years

Tyler always achieved respectable standardised scores above 100 in school tests. Teachers mentioned that he sometimes had trouble expressing difficult feelings appropriately and was quick to make judgements and rush to action before considering alternatives and consequences. Teachers also reported that he sometimes found it difficult to listen to and follow instructions. Tyler was successful in secondary school selection tests in 2012.

Lucy Year 3 Female





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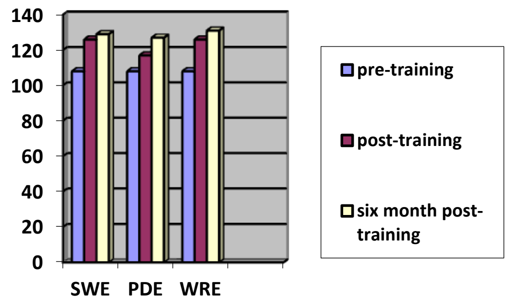

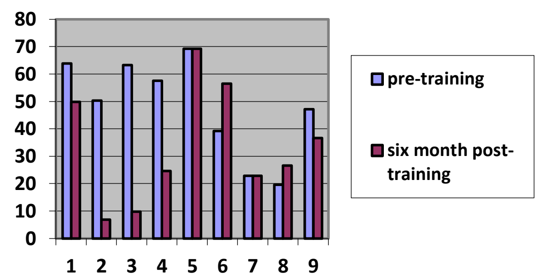

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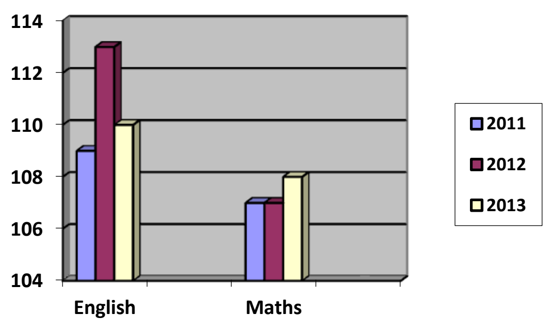


PiE and PiM

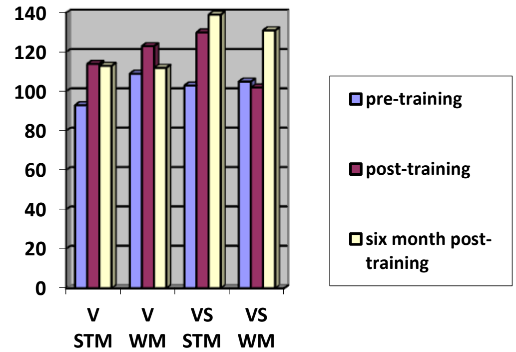
Brief History

One episode of OME in infancy

Lucy was reported by her teachers to be an able child who was underachieving in some areas. In reception she was slow to learn to read, could not appreciate rhyme, and eventually learned to read by memorising whole words, preferring not to blend or segment words. Her early writing was large and mostly incorrectly formed.

Lucy displayed strong mathematical skills in the early years at school, but began to fall behind her peers when progress depended on learning multiplication tables and formal algorithms. One of Lucy's parents reported literacy difficulties at school.

Emily Year 3 Female



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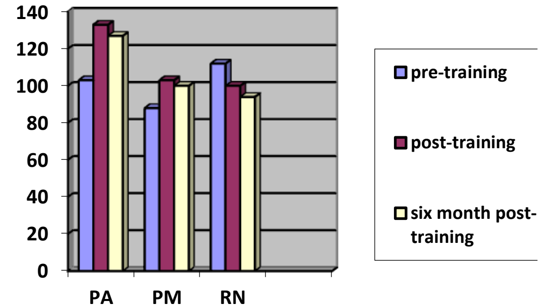

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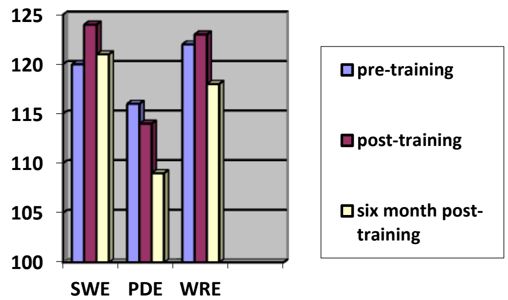

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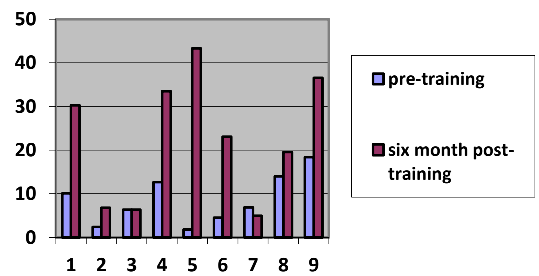

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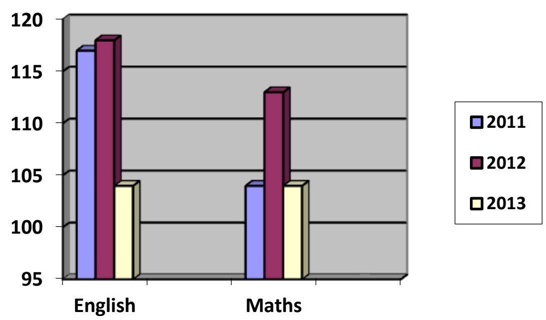


PiE and PiM

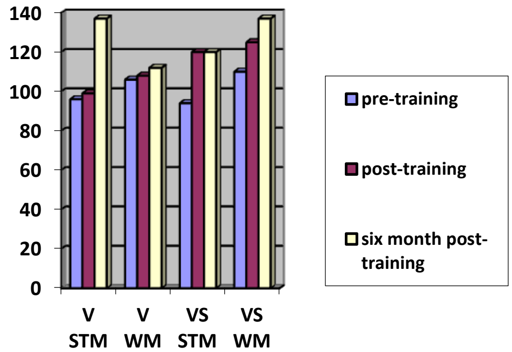
Brief History

One or two episodes of OME during pre-school years

An able child, lacking in confidence, she presented as hesitant in class, and fearful of making mistakes, consequently she worked very slowly and got very little done.

Emily was not referred for extra support in school but parents were advised to support her with phonics and spelling, as she was new to the school and had missed many of the concepts already mastered by her peers.

Sally Year 3 Female



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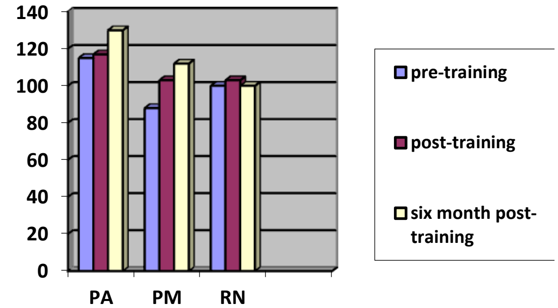

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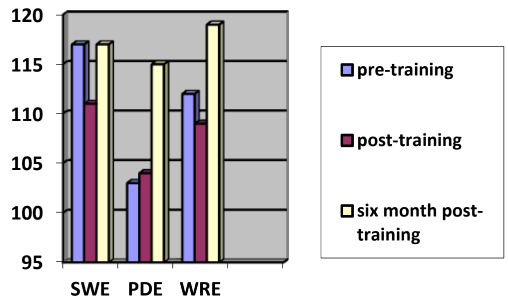

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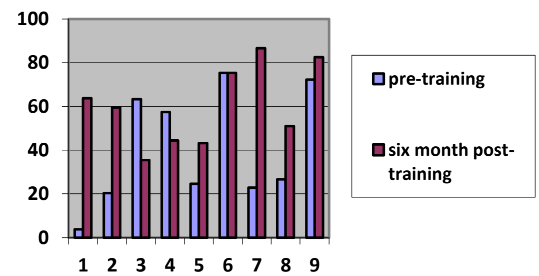

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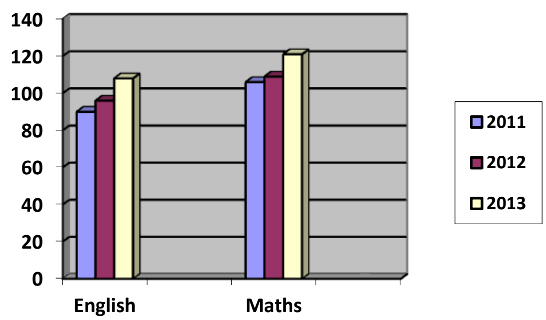


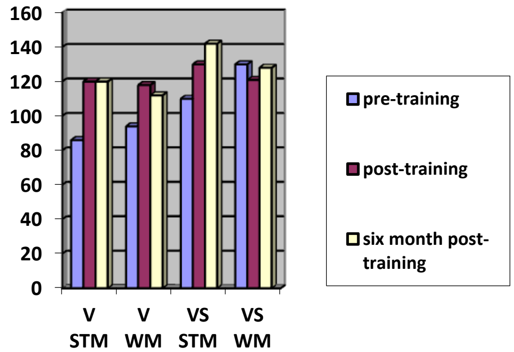
PiE and PiM

Brief History

One episode of OME in infancy

Sally made rapid progress at school during the early years and Reception, but began to struggle with literacy and maths towards the end of Year 1, as the work became more complex. Parents reported that her greatest difficulties were with maths, and she often became upset at home when she could not understand a new concept. She needed to have new concepts presented several times but once she understood, she was able to produce high quality work.

Leah Year 3 Female



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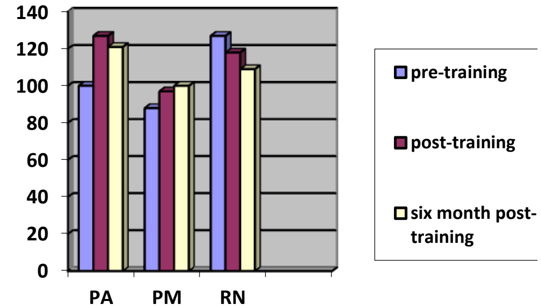

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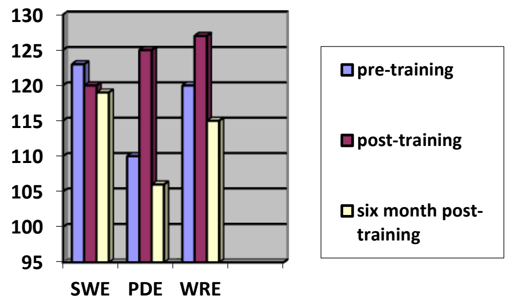

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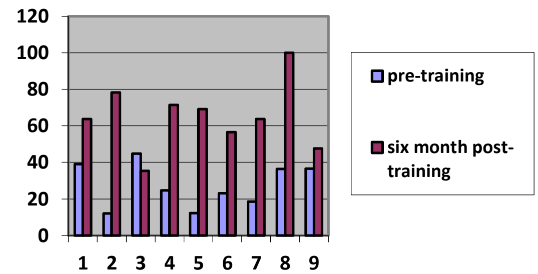

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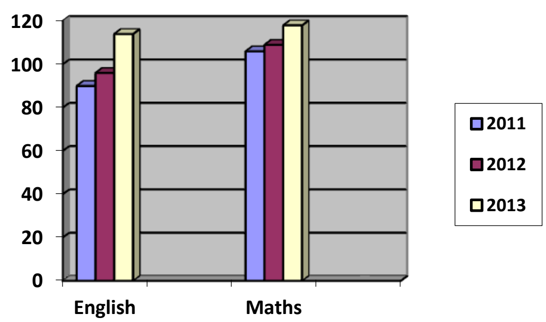


PiE and PiM

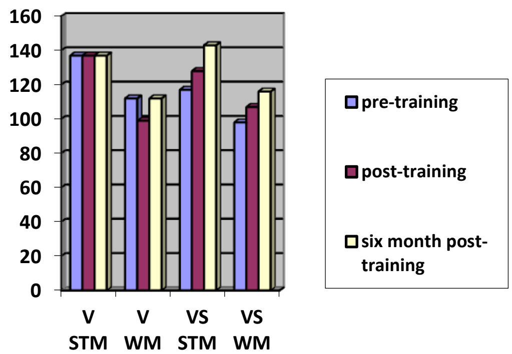
Brief History

One episode of OME during pre-school years

Leah was reported by her teachers to be a conscientious worker, keen to please, who always did her best. She was a happy child who displayed no signs of work related anxiety at school, but parents reported that she was very competitive, and often became very upset at home when she felt other children were doing better than her.

Despite high levels of motivation, Leah found it very difficult to sustain the high levels of progress with literacy and numeracy necessary to keep up with her class. Linking letters and sounds was always particularly difficult and her present school problems in Years 3 and 4 when this study was conducted, related to spelling, learning and applying multiplication tables and telling the time.

Jenna Year 4 Female



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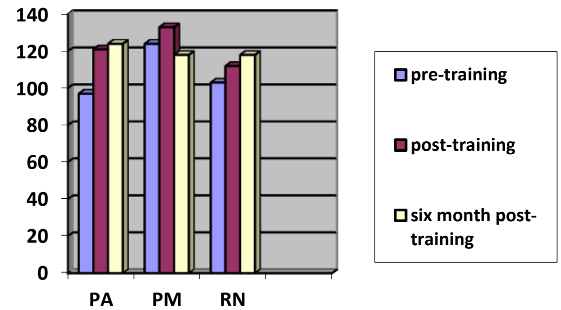

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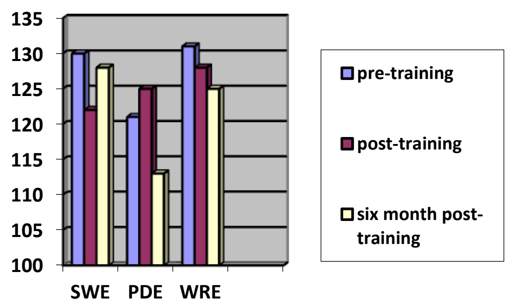
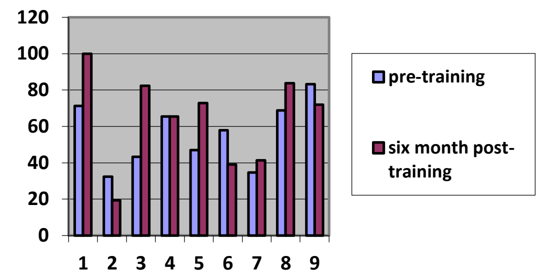


TOWRE



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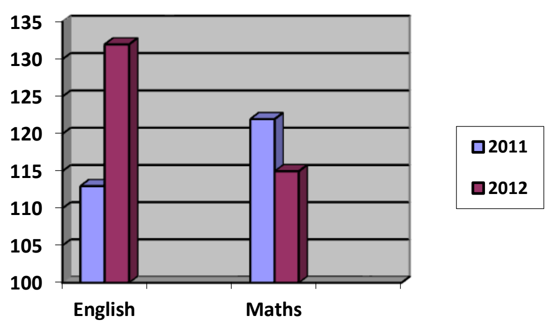


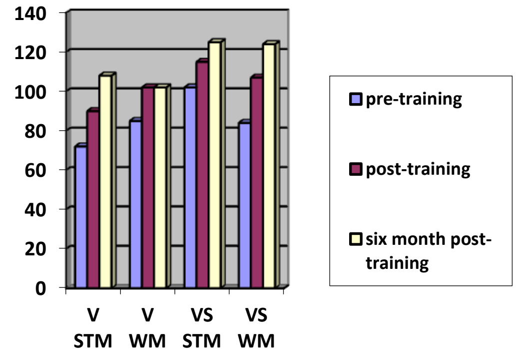
PiE and PiM

Brief History

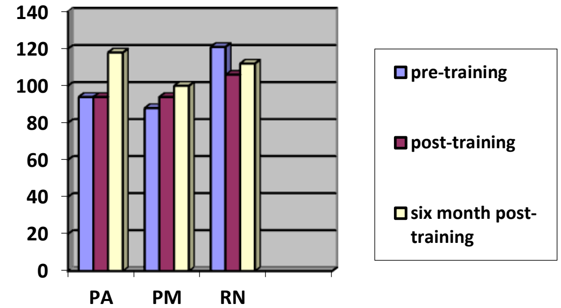
Several episodes of OME from infancy to reception

In reception Jenna always had a runny nose, with green mucus, and often complained of painful ears. She had more difficulty than her peers learning to read, and while her storytelling and oral language skills, including vocabulary, were above average for her age, she found it hard to blend and segment words, and to write. In Year 6 she was reading, writing and spelling at a level above average for her age. Jenna regularly achieved test scores in the above average range in English and maths. Jenna was successful in secondary school selection tests in September 2013.

Cheryl Year 4 Female



AWMA



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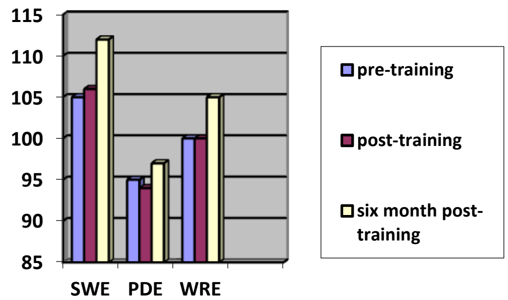

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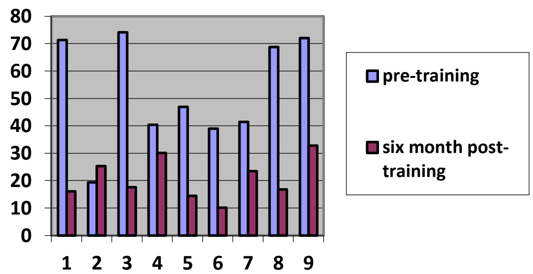

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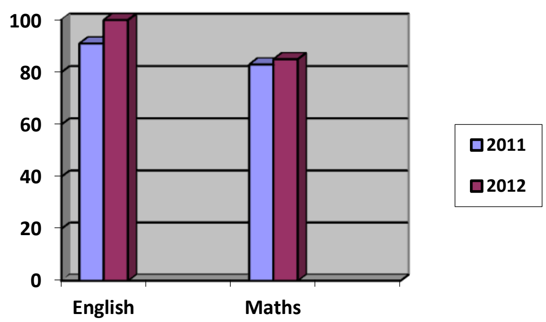


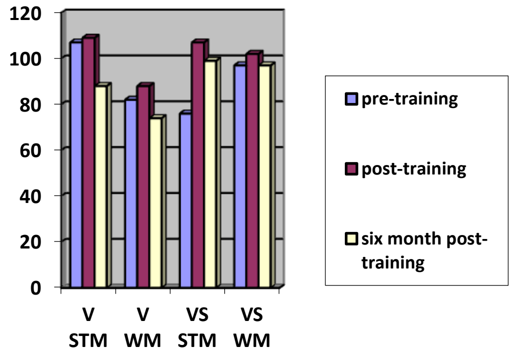
PiE and PiM

Brief History

Several episodes of OME during pre-school years

Cheryl was a quiet child who was unable to blend and segment words, she presented with problems with retention of material, and made slow progress with literacy and maths. Her teachers had not always been aware of the extent of her problems, as she worked very hard, was determined not to stand out from her peers, and produced work of a good standard. Cheryl was unsuccessful in secondary school selection tests in September 2013.

Angel Year 6 Female



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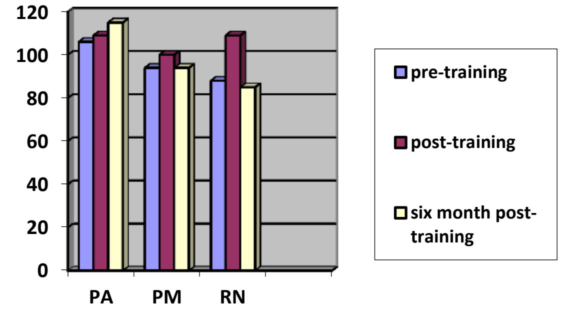

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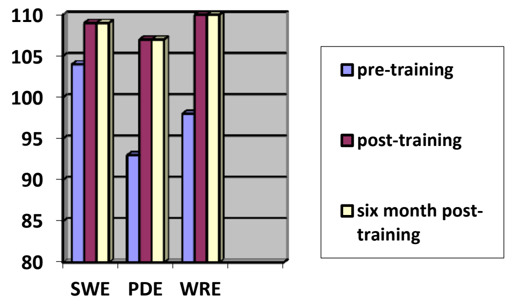

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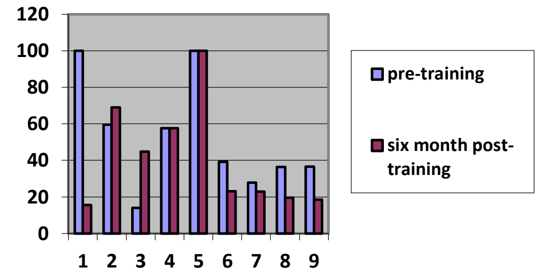

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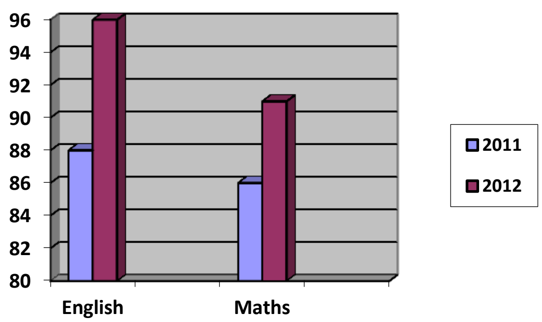


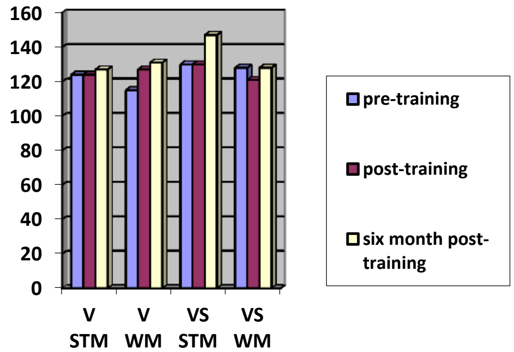
PiE and PiM

Brief History

Two or three episodes of OME during pre-school years

Achieving at the lower end of the average range, and identified as a poor speller, she had been described by former teachers as a ‘daydreamer’. She had been achieving scores in the low average range throughout her school career, and had trouble maintaining attention and concentration. Spelling and writing organisation were particular weaknesses, as well as learning number bonds, multiplication tables and paper and pencil algorithms for calculations such as addition and subtraction with exchange, and long multiplication. She enjoyed school but sometimes lacked concentration during lessons. Angel was unsuccessful in secondary school selection tests in 2011.

Niall | Year 3 | Male



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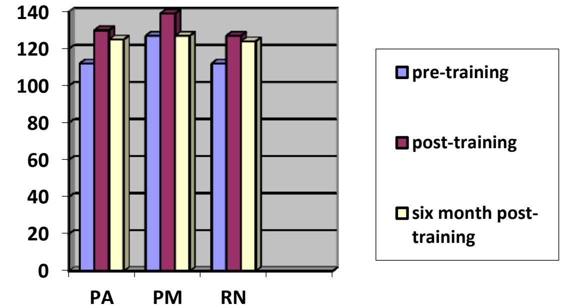

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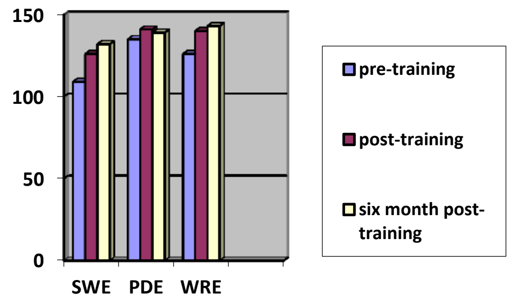

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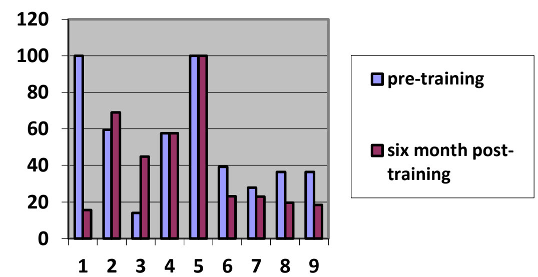

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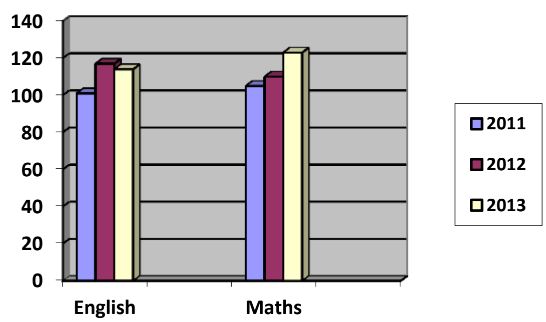
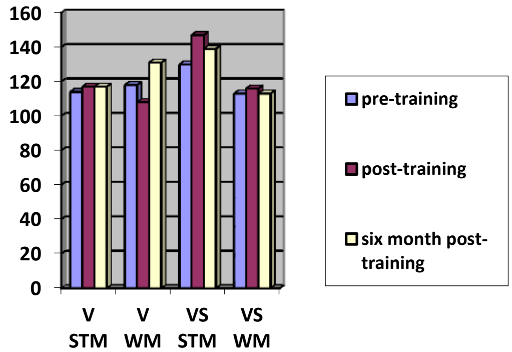
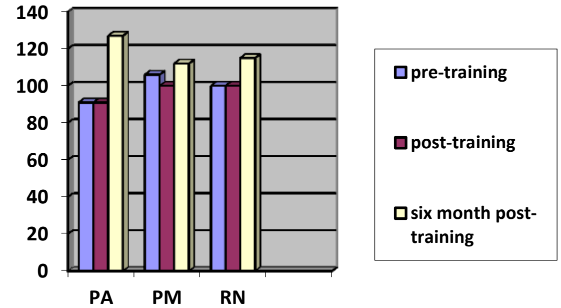


PiE and PiM

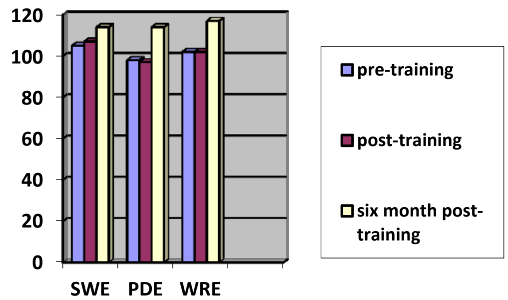
James Year 3 Male

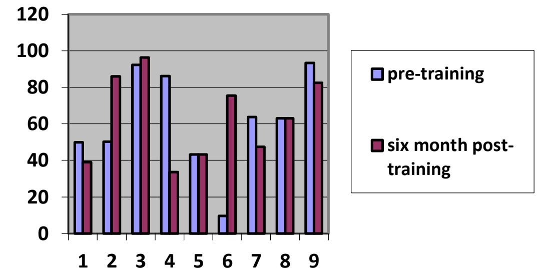




CTOPP

AWMA





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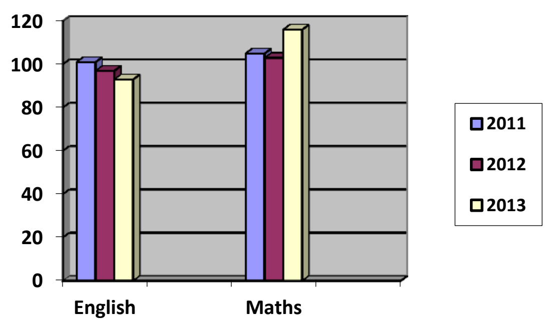
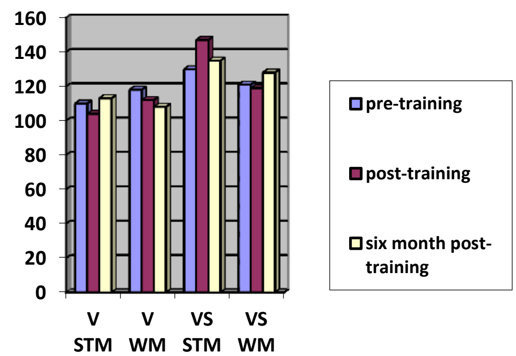


PiE and PiM

Fred Year 3 Male



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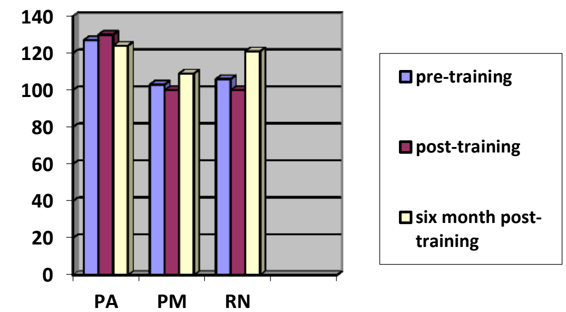

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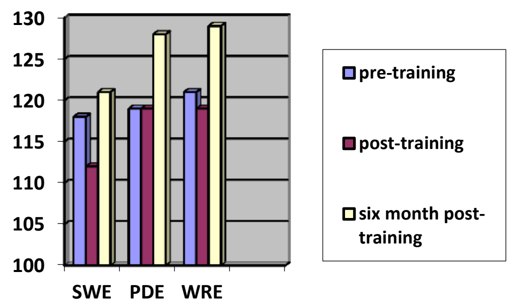

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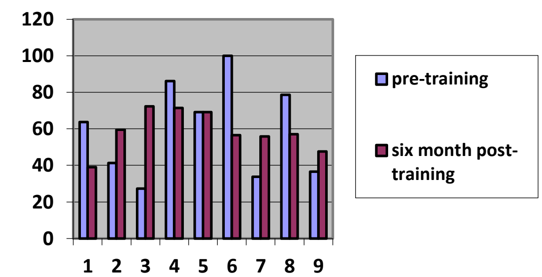

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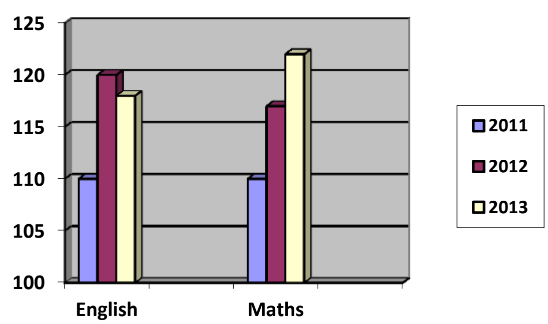
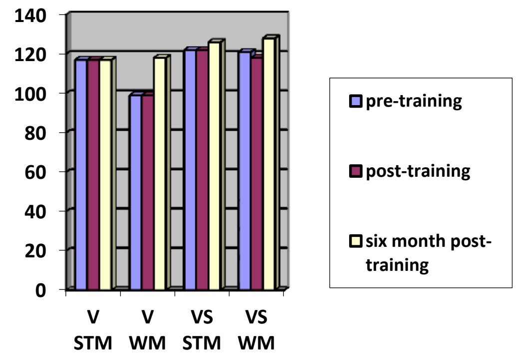


PiE and PiM

Colin Year 3 Male



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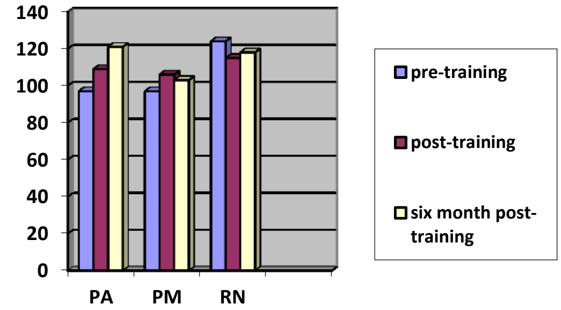

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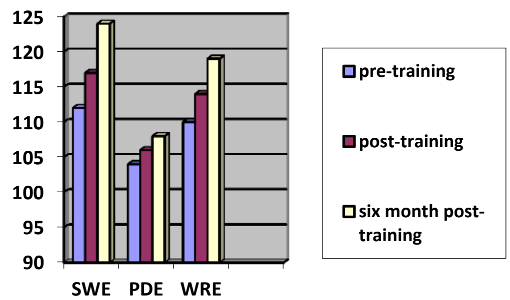

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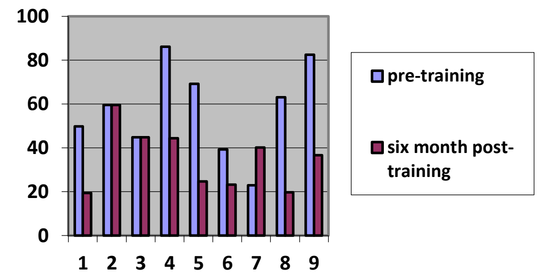

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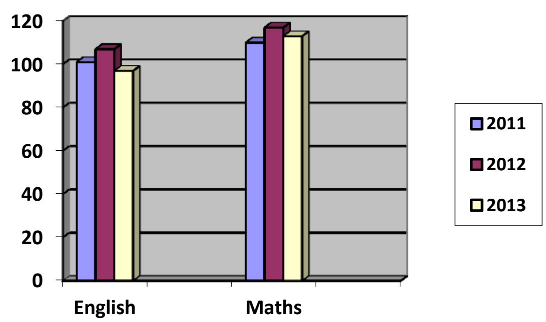
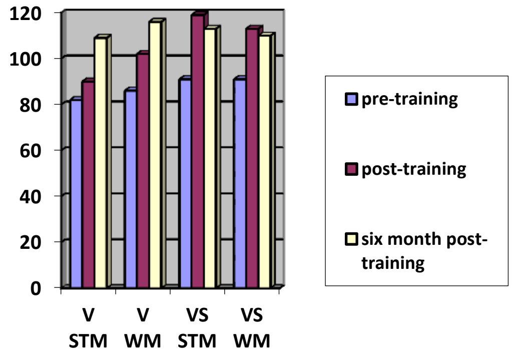


PiE and PiM

Leon Year 5 Male



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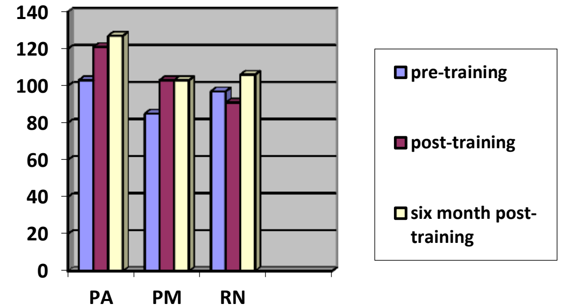

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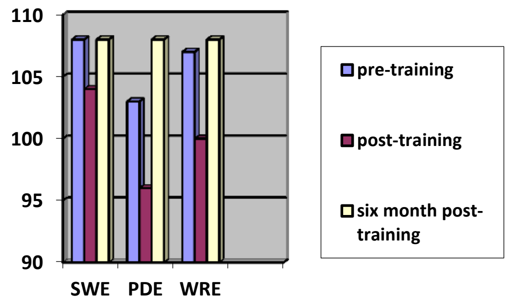

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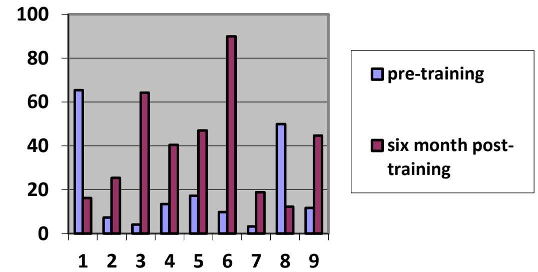

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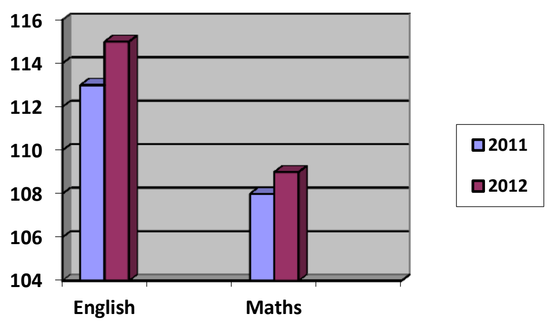
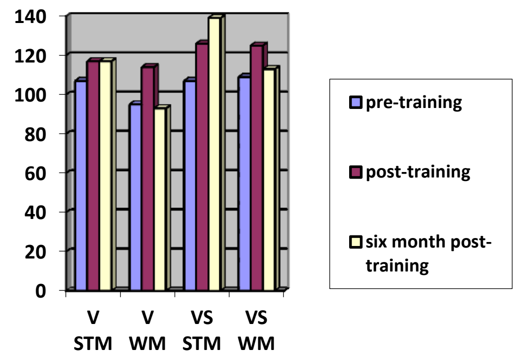


PiE and PiM

Melody Year 3 Female



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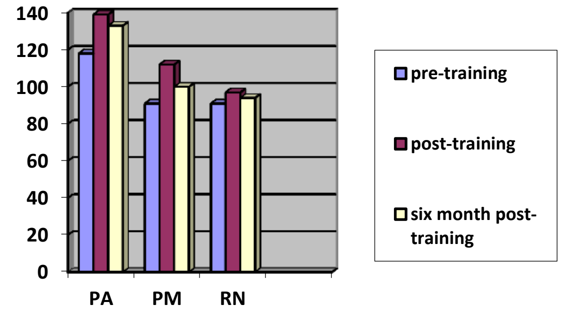

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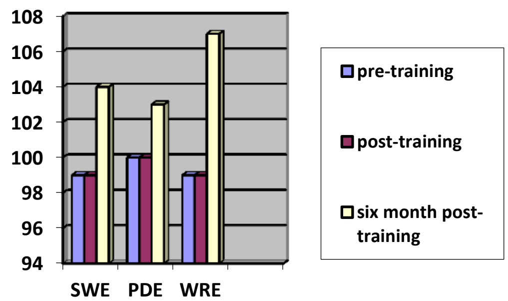

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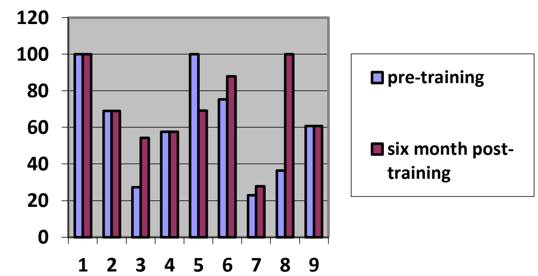

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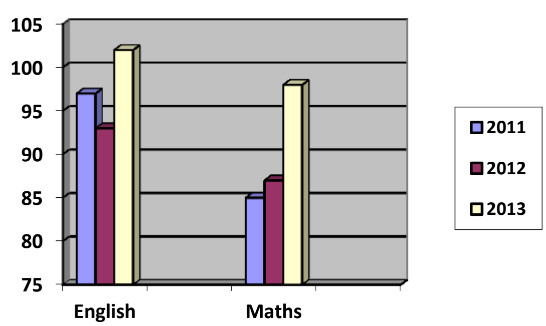
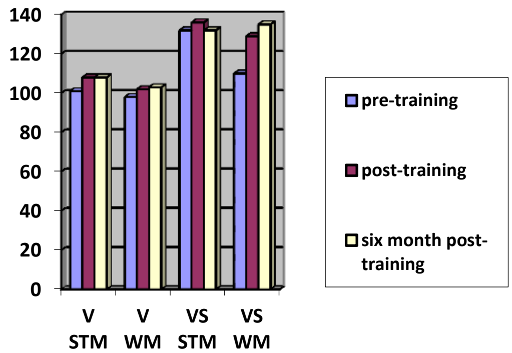


PiE and PiM

Ellie Year 5 Female



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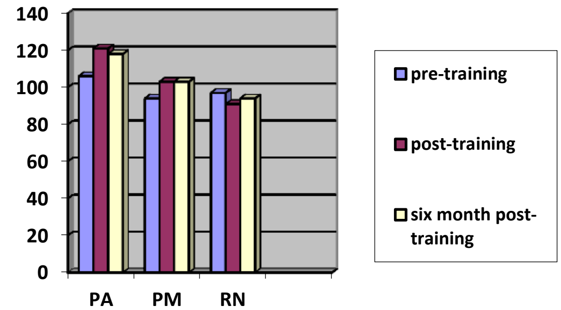

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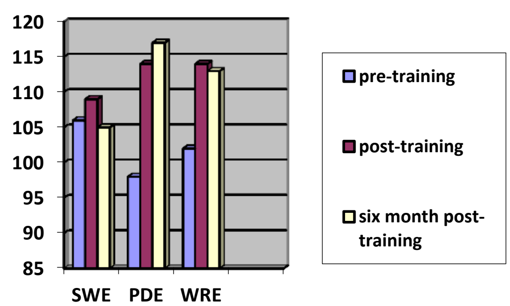

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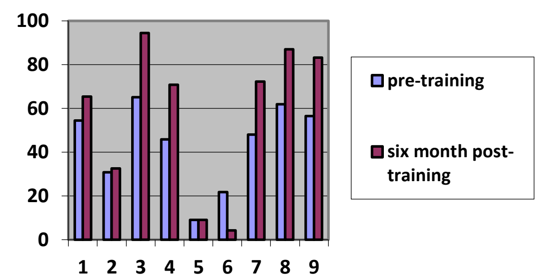

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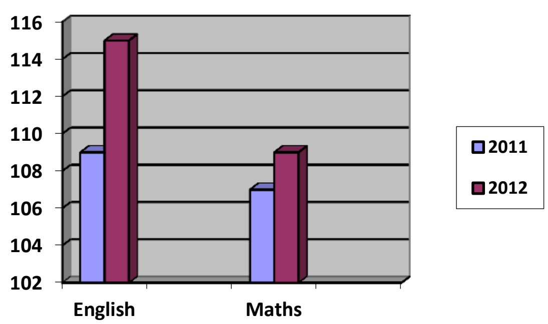
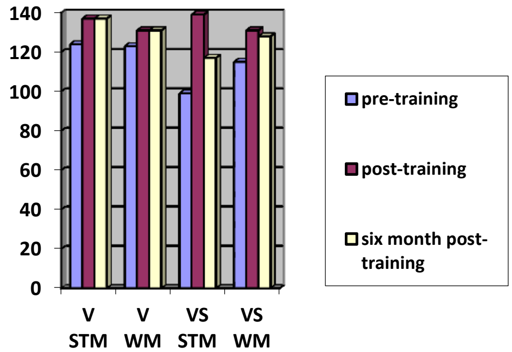


PiE and PiM

Jess Year 3 Female



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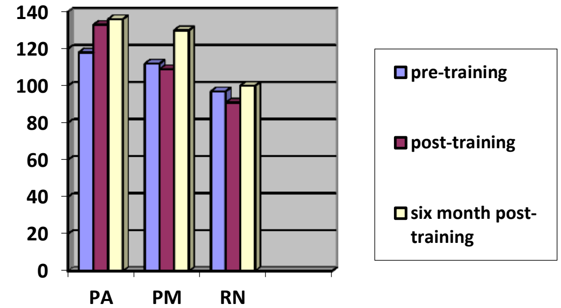

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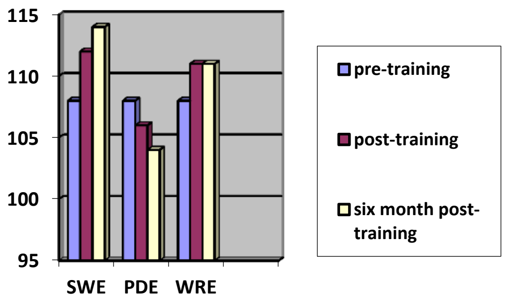

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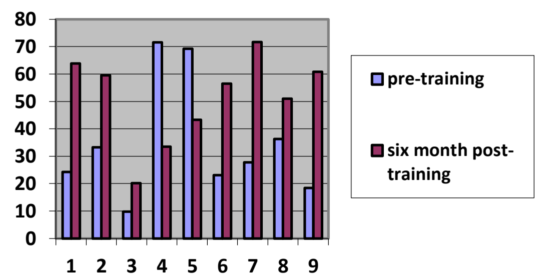

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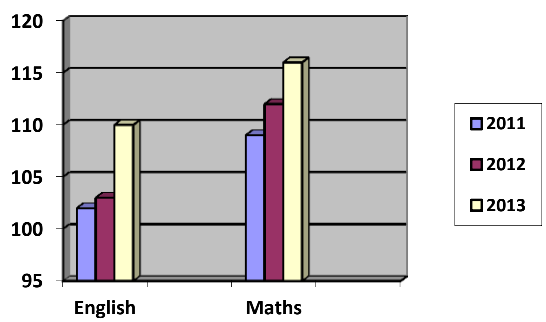
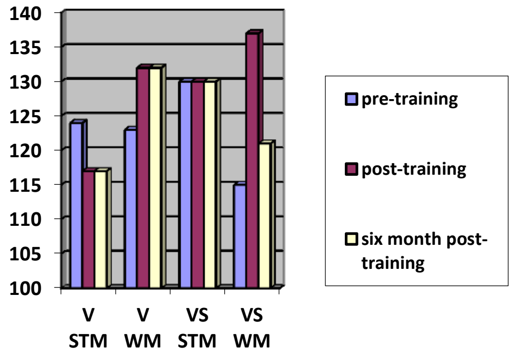
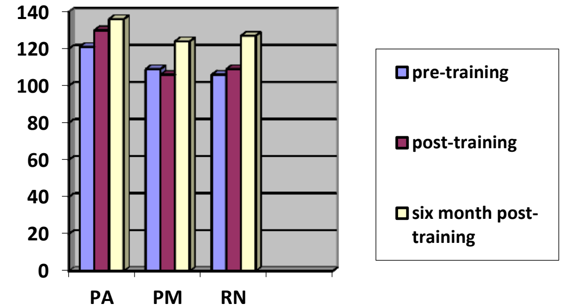


PiE and PiM

Amelia Year 3 Female





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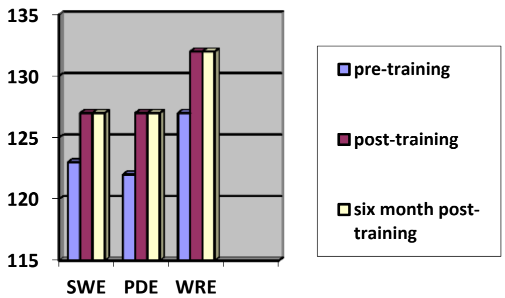
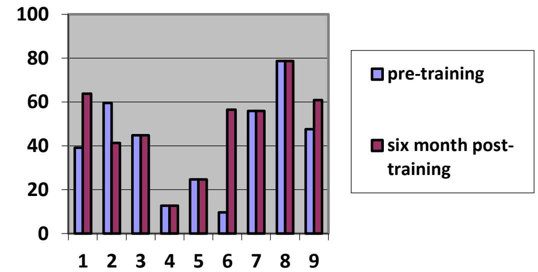
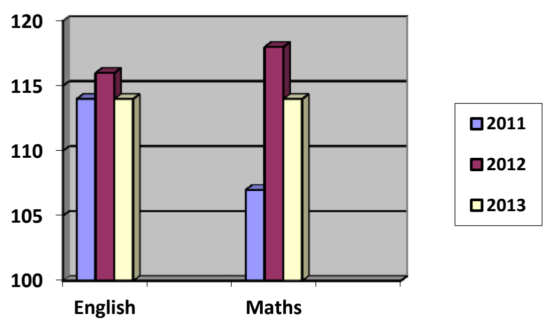
AWMA





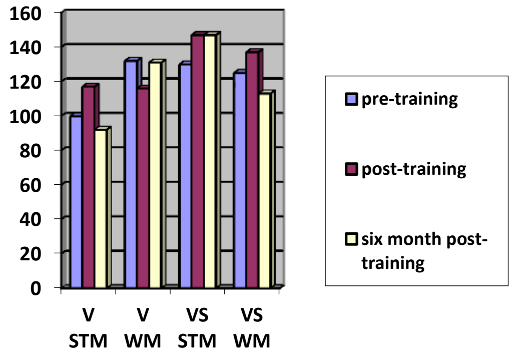
TOWRE

PASS

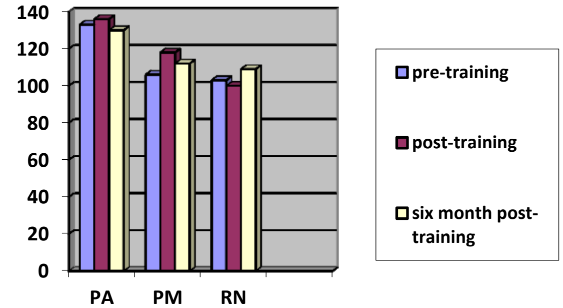


PiE and PiM

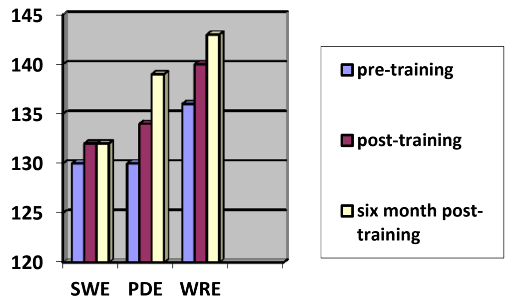
Kathy Year 3 Female



AWMA



CTOPP



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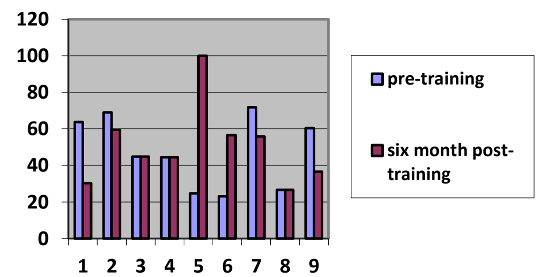
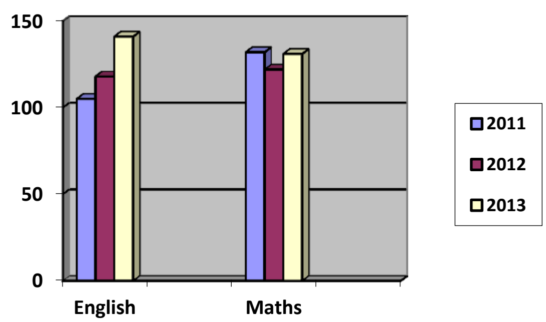
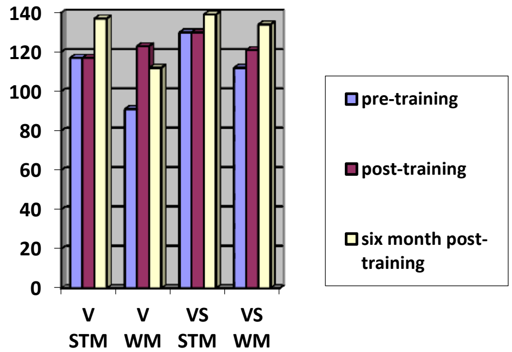


PASS

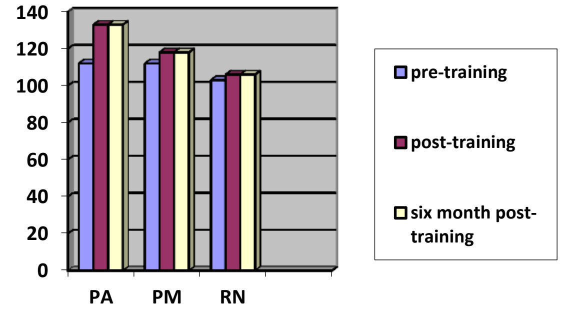


PiE and PiM

Nat Year 3 Female



AWMA



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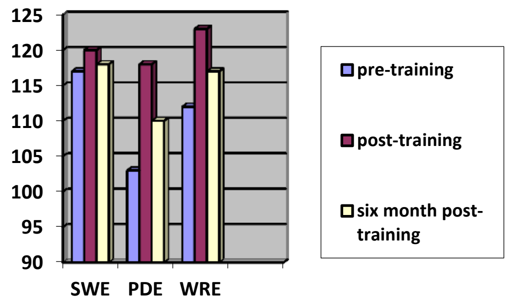

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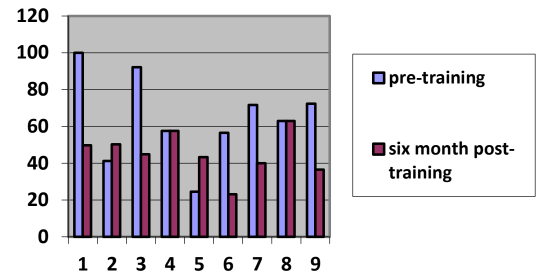

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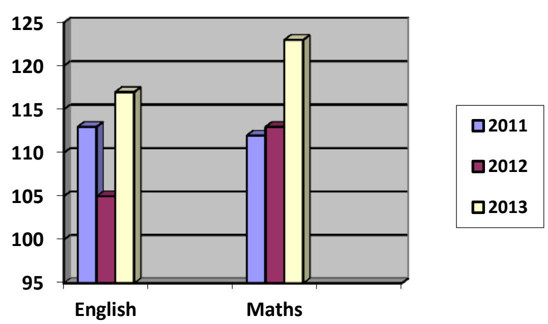
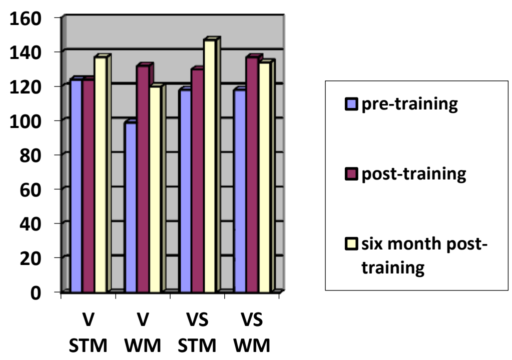
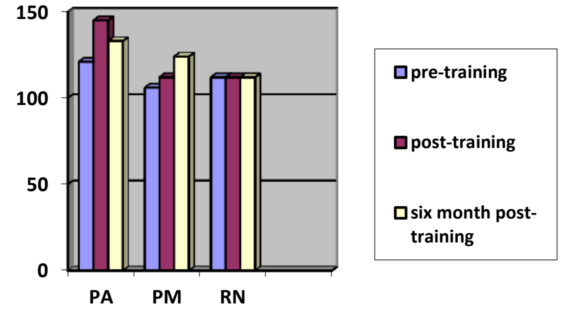


PiE and PiM

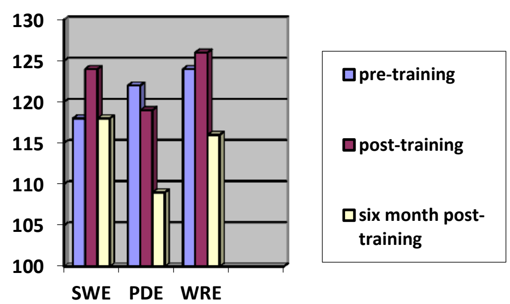
Mandy Year 3 Female

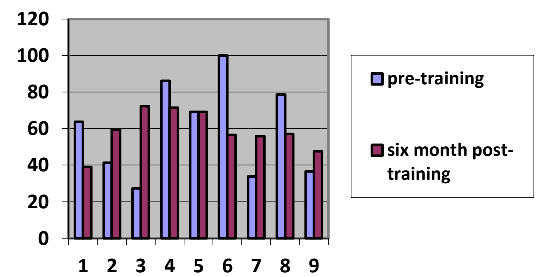




CTOPP

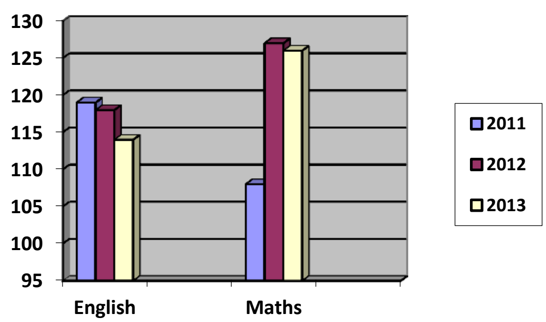
AWMA





TOWRE

PASS



PiE and PiM