Working Memory in Children and its Relationship to Academic Achievement and Behaviour

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Abstract

For children, Working Memory WM capacity underpins the ability to acquire knowledge and skills in school curriculum areas. The present study aimed to examine WM function in a group of New Zealand primary school children, and to investigate a possible association between reading and maths achievement and WM function. It also investigated whether WM deficits are reflected in children's behaviours as observed by teachers in the classroom and parents at home. A related aim investigated the prevalence of learning disorders or experiences that have been linked to WM deficits.

WM ability was assessed with a group of 60 children aged 9 – 11 years using the Automated Working Memory Assessment Screener, AWMA Screener, or fully tested on the Automated Working Memory Assessment – Long version AWMA-L which assesses both verbal and visuo-spatial Short Term Memory STM and WM components. Twenty percent were found to have low scores in at least one component of WM. Two groups of children were selected from the 60 children based on their reading and maths achievement,13 average and 16 below average. Eighty three percent of children with low WM were below average on academic performance. The below average academic group performed significantly lower than the average academic group on all but one subtest of the AWMA-L. There was a significant difference in performance by age for one of the verbal short term memory subtests of the AWMA-L, but no between group significant differences for sex or ethnicity.

The two groups of children were rated by their teachers on the WM Rating Scale WMRS, and parents on the WMRS-for parents WMRS-PC. The children with low WM scores were rated as having more frequent behaviours relating to WM problems than children with average and above average WM. Children in all WM ability groups were reported as having experiences or disorders related to WM deficits. The results corroborate previous findings and may be of interest to

educators in that WM ability is a building block that may affect the acquisition of information during learning episodes at school. The child with low WM may not have inherent difficulty with the academic work, but in taking in the information. Assessment of WM may identify children who may need to learn in a different way in order to reach their academic potential.

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Chapter 1
Introduction

The current research was born out of a suggestion that children with *working memory* (WM) problems would be likely to have difficulties in certain areas of everyday functioning, and that these difficulties would flow on to impact performance and/or achievement at school. As background to a possible study a review of the literature was undertaken in the areas of WM, its development, and its relationship to academic performance and behaviour. This review led onto looking into how WM is also related to specific conditions, disorders, and circumstances that may commonly affect otherwise typically developing school children.

Overall, the literature review provided a compelling basis for the current study – there was no clear evidence of how frequently WM was a problem and there had been no work conducted in this area in New Zealand. Accordingly the aims of the current study were to:

- Explore WM ability in a cohort of New Zealand school children.
- Explore a possible relationship between WM and achievement in reading and maths according to national standards within the New Zealand school curriculum.
- Explore whether behaviours typical of WM deficits were apparent (as reported by teachers and parents) in children who had been identified as having low WM.
- Explore whether children with low WM were more likely to have been diagnosed with specific disorders, or had experienced certain events.

Chapters 2 - 4 include aspects of the literature review. Chapter two provides a brief overview of the construct of WM, including theory and models that explain the construct and how this is applied to the development of WM in children.

Chapter three presents a review of the relationship between WM and academic achievement (particularly in the areas of reading and maths where most research has been conducted). The chapter also reviews WM and what it may behaviourally look like in the classroom to teachers. Additionally, the chapter also reviews WM behaviour rated by parents, and briefly looks at observational research in the classroom.

Chapter four reviews conditions, disorders and circumstances that have been associated with WM deficits in children that have been related to under achievement in reading and maths. It also reviews studies that have investigated WM training. This chapter concentrates on otherwise typical children that are attending mainstream schooling that may be having difficulties or challenges with learning progression.

Chapter five covers the aims and hypothesis for the current study in light of the reviewed literature, chapters six and seven cover the method and results sections respectively. The discussion with limitations of the study and suggestions for further research is covered in chapter eight.

Chapter 2

Working Memory

Throughout the day people are required to store and process information for a short time period whilst engaging in a multitude of day to day tasks and activities, (e.g., when remembering phone numbers to dial, performing a mental calculation, or taking a quick mental inventory of what is not in the cupboard to write a shopping list). This type of memory is known as *working memory* (WM) and is important to thinking and reasoning and underpins learning (Alloway & Alloway, 2010). During the normal course of their day children are constantly engaging in similar tasks (e.g., remembering a list of items a parent has told them to bring out of their room, following instructions in class, or completing mental maths problems). The first section of this chapter includes a brief overview of WM, its functions, and the theoretical underpinnings of a model of WM. The second part of the chapter covers WM as it applies to children.

It is widely agreed that WM is a construct that integrates and organises information in conscious operation. New information is stored, whilst other information is manipulated and/or retrieved for the purpose of additional information processing simultaneously (Becker & Morris, 1999). The most well know model of WM is one proposed by Baddeley and Hitch (1974), and Baddeley (2000). The term WM is used interchangeably in many research articles, some use it to refer to the measurement of *short term memory* (STM), storage only of information, some use it to refer to measurement of storage plus processing tasks and yet others use it when referring to the WM model. For the purposes of this research study, the term working memory will be used to refer to the processes of both storage and processing, unless otherwise specified.

Baddeley and Hitch's Model of Working Memory

Baddeley and Hitch's (1974) original model holds that there are three main components to WM: the p*honological loop*, the *visuo-spatial sketchpad*, and the *central executive*. The concept of the *episodic buffer* was added later to the model and helps explain the fit of *long term memory* (LTM) within the active information processing that takes place in WM (Baddeley, 2000).

Phonological loop. This component of WM is a passive storage facility for speech and sound based information and is divided into the *phonological store* and the a*rticulatory rehearsal mechanism* (Baddeley & Hitch, 1974). The phonological store is described as a passive *slave system* (Baddeley, 1986), as it is purely a storage facility and is susceptible to rapid decay. It is thought to hold approximately two seconds only of speech based information (Baddeley & Hitch, 1974). The phonological loop is what many researchers refer to when speaking about STM for verbal information, sometimes referred to as *verbal STM*.

The *articulatory rehearsal mechanism* sub-component of the phonological loop is responsible for rehearsal of information in order to prevent rapid decay. Verbal rehearsal serves to expand the capacity of the phonological loop. Evidence to support the rehearsal mechanism of the phonological loop has been explained by experiments illustrating that the length of words being rehearsed effect their recall, (i.e., recall for words that are shorter is better than for words that are longer), because shorter words can be rehearsed more quickly, refreshing the memory trace in the phonological loop quicker than words that are longer with more syllables. This phenomenon is known as *the word length effect* (Baddeley & Hitch, 1974) and has been supported in studies in different languages (Ellis & Hennelly, 1980; Stigler, Lee, & Stevenson, 1986).

Verbal auditory information enters directly into the phonological loop as it is already in a phonological form. The proposition of the phonological loop being specifically phonemically based is supported by evidence of the *phonological similarity effect* in tasks of verbal recall, that is; lists of letters or words that have a similar sound (e.g., D, B, V or cat, rat, mat) are harder to recall than lists that contain letters or words that do not have a similar sound (Conrad & Hull, 1964; Baddeley, 1966). These researchers have concluded that similar speech based sounds and consequently poorer discrimination of verbal material gives rise to confused and decreased recall from short term storage for speech based information.

Visual information can also enter the phonological loop if a person has a name or label for this information. Therefore visual information can be modified into a phonological form and consequently have optional entry into the phonological store where it can be rehearsed phonetically if need be (Henry, 2012). Importantly, recoding visual information in this way changes visual STM into phonological STM. However, repeated, simultaneous verbalisation of meaningless sounds, (e.g., yip, yip, yip) can interfere with the articulatory rehearsal mechanism and inhibit recoding of visual information, preventing visual information from entering the phonological store. Additionally suppressing articulatory rehearsal this way removes the phonological similarity effect for visual information but not for auditory information (Baddeley, Lewis, & Vallar, 1984; Baddeley, Thomson, & Buchanan, 1975).

The mean total of items recalled in a test of phonological STM is known as *memory span,* the size or capacity of memory span is affected by rehearsal speed. Furthermore, rehearsal speed is influenced by the articulation rate or speech rate of individual persons. Importantly, memory span is a function of word length and reading rate (Baddeley & Hitch, 1974).

Visuo-spatial sketchpad. This component of Baddeley and Hitch's (1974) WM model is responsible for the passive storage of visuo-spatial information and is subdivided into visual and spatial components, which, like the phonological loop are sensitive to rapid decay. The visual component stores information relating to colour and form of an object, whereas the spatial component stores information relating to where in space the object is situated (Logie, 1995). Storage of visual or spatial information in the visuo-spatial sketchpad is referred to as *visuo-/spatial STM*. Logie (1995) proposes a *visual cache* that stores visual aspects of stimuli and the *inner scribe* that assists storage, representations of movement sequences, and performs rehearsal.

Research has been undertaken to investigate the question of separation between both the visual and spatial subcomponents (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999; Logie & Marchetti, 1991; Darling, Della Sala, & Logie, 2007). The general findings are that there is support for separate mechanisms, in that, interference in the same modality as the material to be remembered, either both visual or both spatial, causes a larger deficit in recall than if interference was of the opposite modality of the to be remembered stimulus.

Central executive. This component of Baddeley and Hitch's (1974) original WM model has been redefined over the years and is now considered to be responsible for the management and allocation of attention (switching, dividing, focusing) between the phonological loop, visuo-spatial sketchpad, and the episodic buffer. It is now said to have no storage capacity of its own (Baddeley, 2007).The attentional function of the central executive is important when novel situations or information arise and usual ways of responding are not suitable. As a result more attention is required for new planning and execution of new ideas and strategies. Neuro-imaging studies with adults help corroborate a general resource such as the central executive. Chein, Moore & Conway (2011) found that the same areas of the brain activates when tasks assessing both verbal and visuo-spatial WM components are used.

The central executive has been equated with the *executive functions* of cognitive psychology in that the latter construct has been proposed to be responsible for the control and management of several higher order cognitive processes correlated to frontal lobe functioning (Kane & Engel, 2002). The main executive functions are: *planning/problem solving, set shifting/switching, fluency, inhibition, working memory, and self monitoring* (Henry, 2012). Just like the central executive of the WM model, executive functioning skills are useful for negotiating new situations where new responses are needed. The executive functions of updating, set shifting, and inhibition have shown to be both related and separate when performing complex tasks, so care must be taken in assessment when testing such functions and making inferences (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

Episodic buffer. The episodic buffer was not originally included in Baddeley and Hitch's (1974) original WM model. However a revision of the model was undertaken and the episodic buffer was included. It is proposed to possess a temporary store for information from many modalities. It also operates as an interface between the two slave storage systems and long term memory, which is controlled by the central executive which binds information and processes it for further use contemporaneously, or in the future (Baddeley, 2000). This revision of the earlier WM model assists in; explaining the role of LTM, how it is activated and utilised for processing and aiding current experience (episodes), it also explains how the buffer further adds to crystallized knowledge in LTM.

Support for this fourth component of WM is evidenced in studies of recall of non-complex visual stimuli (Schumann-Hengsteler, Strobl, & Zoelch, 2003) and recall of symmetrical visual stimuli (Rossi-Arnaud, Pieroni, & Baddeley, 2006). In these studies the episodic buffer acted to bind chunks of stimuli with representations held in LTM irrespective of any demands made on the phonological loop or central executive. Support for the episodic buffer also comes from studies of verbal information where memory for familiar words is better than memory for unfamiliar words (Hulme, Maughan, & Brown, 1991).

Figure 2.1 illustrates the revision of Baddeley and Hitch's (1974) WM model. The unshaded area's represent fluid intelligence where conscious processing takes place, directing attention for current activities. The greyed area illustrates operational systems where information can be stored in long term memory (Baddeley, 2000).

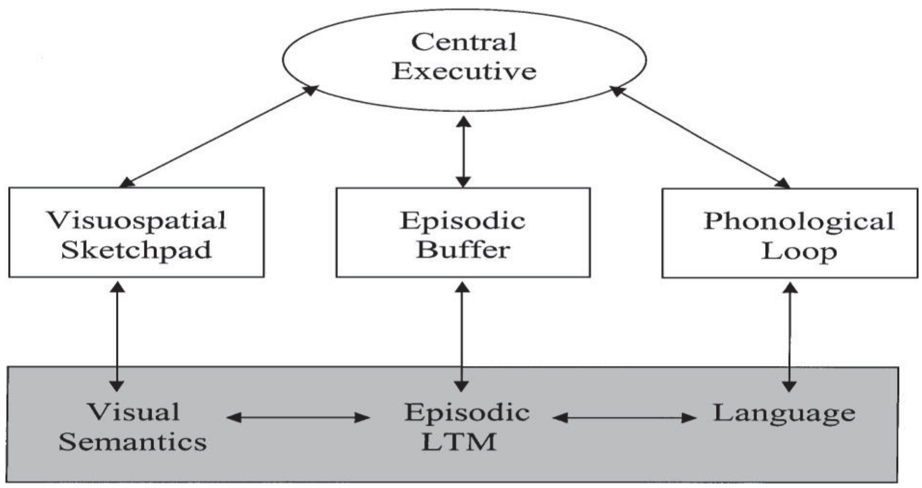

Figure 2.1. Model of working memory, revised (Baddeley, 2000).

Summary

For the purposes of thinking, reasoning, and learning the WM model is described as a limited system directed by a central executive that interacts with two passive storage systems. One stores speech based information, that is maintained through articulatory rehearsal – the phonological loop, and one that stores and refreshes visuo-spatial information – the visuo-spatial sketchpad. The episodic buffer stores and integrates information between the passive storage systems and LTM, thereby making sense of current episodes. The central executive is responsible for the overarching control of all subcomponents by flexibly focusing, dividing, and switching attention. The next section will focus on how children's WM develops within the WM framework developed by Baddeley and Hitch (1974), Baddeley (2000).

Development of WM in Children

Typically developing children develop at the rate expected, and function academically within a range that is usual for their age (Henry, 2012) and in line with the WM model, the memory span of typically developing children increases with age for verbal and visual material (Alloway, 2007). In a study investigating the WM development of 702 children from 4 to 11 years of age, Alloway, Gathercole, and Pickering (2006) found support for Baddeley and Hitch's (1974) WM model. Using assessments to measure verbal and visuo-spatial STM and verbal and visuo-spatial WM, they found incremental increases in accuracy across all age groups; 4 to 6, 7 to 8, and 9 to 11 years in all measures. They also found that WM is best characterised across developmental ages as a three factor model consisting of domain specific (separate) storage for verbal and visuo-spatial information, that shares a domain general processing resource, assumed to be the central executive.

Alloway et al. (2006) additionally found that the scores on visuo-spatial STM and visuo-spatial WM tasks were more highly correlated for the four to six year old age group than older age groups. This suggests either that younger children draw more on executive resources when concentrating on visual storage tasks or that the visuo-spatial storage measures used in the assessments were more dynamic rather than static, which draws more on the central executive resource (Alloway et al., 2006).

Jarvis & Gathercole (2003) also found that visuo-spatial STM and WM to be correlated in 11 year old children, but found in 14 year olds that visuo-spatial WM was significantly more correlated to verbal WM, surmising that superior processing speed of the older group allowed them to recode visual locations, in the visuo-spatial WM task, into verbal labels for later recall. Alloway et al.'s (2006) research also found that the correlations between visuo-spatial STM and verbal STM increase through the age groups, 4 to 6, to 7 to 11 years. This finding adds support for the view that younger children store visual information as visual representations, but as they get older assign verbal labels to visual information and use verbal rehearsal to assist recall (Baddeley & Hitch, 1974). Furthermore the Alloway et al. (2006) finding supports other research that has found word length effects for visually presented stimuli at approximately seven to eight years of age (Hitch, Halliday, Dodd & Littler, 1989; Hitch, Halliday, Schaafstal, & Heffernan, 1991).

To illustrate the developmental growth of WM that Alloway et al. (2006) found in their study, Figure 2.2 shows the comparison from 4 to 10.5 years, across verbal and visuo-spatial STM and WM components, using tasks that assess each component.

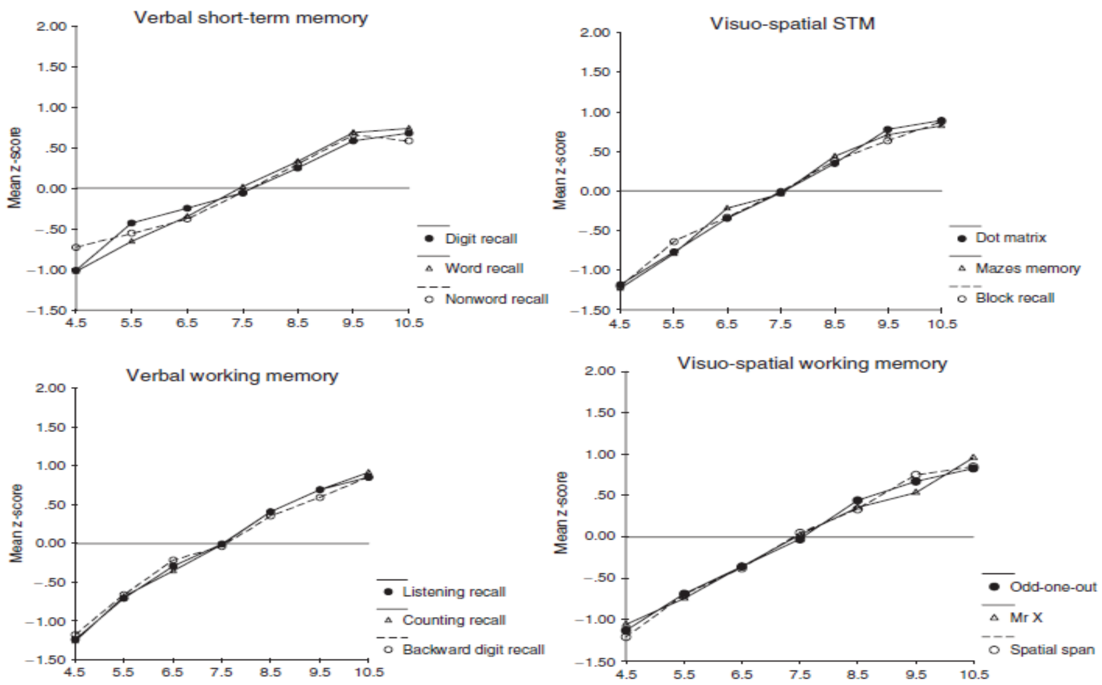

Figure 2.2. Growth in verbal and visuo-spatial STM and WM, from ages 4 – 10.5 years (Alloway et al. 2006).

Even though there is incremental growth of WM during development there is large individual variation in performance that can be measured with WM assessments. Typically in a classroom of 30 children there would be a range of five years of normal WM development between the lowest scoring children and the highest scoring children (Alloway, 2007; Alloway et al., 2006). This could impact the learning acquisition of children, and have implications for classroom teaching. More generally, different studies looking at certain aspects of WM have found support for the development of different components of WM in children:

Phonological loop. Increases in memory span for words has been found in children from the ages of 4 to 11 years, just as it has been found with adults (Henry, 1991a; Hitch et al., 1989). Word length effects have also been found, which has been drawn on to assume that rehearsal is used by children (Hitch et al., 1989). The basic premise is that children speak more slowly than adults, and therefore rehearse at a slower rate. But as they age, articulation rate increases and it follows that rehearsal rate increases, improving memory span.

However, investigators have found little evidence of rehearsal use in children reliably before seven or eight years of age (Cuvo, 1975; Ferguson, Bowey, & Tilley, 2002; Gathercole & Adams, 1993; Gathercole, Adams, & Hitch, 1994; Henry, 1991a; Henry, 1991b; Ornstein, Naus, & Stone, 1977). This suggests that the increase in memory span in young children is due to a combination of factors such as; the familiarity of the stimulus, which brings into the equation the contribution of LTM (Henry & Millar, 1991). The use of rehearsal rather than the increase in speed of rehearsal (Henry, 1991a). There is also the suggestion that differential methods in span scoring and modalities of presentation across studies may have a bearing on results yielded (Henry & Millar, 1991; Henry, Turner, Smith, & Leather, 2000). Increasing memory span as age increases also supports the idea that information processing becomes a more efficient process with age (Case, Kurland, & Goldberg, 1982).

Visuo-spatial sketchpad. Research looking at children’s visuo-spatial memory across developmental age groups has found that memory for visual tasks is better and develops faster than memory for spatial tasks (Hamilton, Coates, & Heffernan, 2003; Logie & Pearson, 1997; Pickering, Gathercole, Hall, & Lloyd, 2001). Closer inspection of the task format of visual and spatial tasks used in assessment revealed that static presentation, (i.e., no movement) in visual tasks, and dynamic presentation, (i.e., movement), in spatial tasks, could explain differences, because static tasks were found to have better recall than dynamic tasks (Pickering et al., 2001). Furthermore, dynamic tasks utilise more central executive resources (Alloway et al., 2006; Logie, 1995). Taken as a whole this indicates in assessment, that researchers or clinicians need to be mindful of this separation between visual and spatial STM and WM and select measures that assess both modalities and ensure the STM measures used are more static in nature.

Central executive. Returning to Alloway et al.'s (2006) study they found developmental increases in verbal WM and visuo-spatial WM across their sampled age groups. Gathercole, Pickering, Ambridge and Wearing (2004) also found these increases in children ranging in age from 4 to 15 years but their finding is limited to verbal WM as they did not investigate visuo-spatial WM. These developmental increases in WM span were assessed using *complex span tasks*. Baddeley and Logie (1999) purport that complex span tasks assess central executive functioning by requiring a processing component and a storage component to the task. Accordingly, the central executive attends to certain information in the task – the processing requirement, (e.g., verbal; reading, judging veracity of a sentence, or visuo-spatial; choosing the odd shape out from three presented shapes). Simultaneously the storage requirement is either; phonological loop, storing lists of words, or visuo-spatial sketchpad; storing locations of a shape which will need to be recalled later.

Episodic buffer. As previously mentioned the increase in memory span with age may also be influenced by associations in LTM. One perspective is that of *redintegration* at retrieval, this is where a word can be retrieved based on a partial memory trace coupled with knowledge held in LTM of known forms of words (Monnier & Bonthoux, 2011). Irrespective of the point at which long term knowledge is activated and utilized, it is proposed that the contribution of LTM aids in the recall of the item or word but not its serial order in a sequence of words given (Gathercole, Pickering, Hall & Peaker, 2001).

Turner, Henry, Smith, and Brown (2004) found reintegration is called up on by children from the ages of 5 to 10 years. When a memory task involves naming recall, the more familiar the item, the higher the benefit of lexical knowledge. They also found interestingly that there was a significant increase in accurate recall of words in a rhyming condition across the age groups whether the rhyming words were easy, difficult, or non-words, highlighting that phonological knowledge of words was important irrespective of word difficulty.

Monnier & Bonthoux (2011) found in a sample of children aged five and nine years that long term semantic knowledge influenced verbal recall. Children were presented lists of words from similar semantic categories and dissimilar semantically categories. The finding suggests support for the redintegration hypothesis in that, knowledge of the semantic category prompts retrieval to assist reconstruction of the decaying memory trace for a word belonging to that semantic category. The five year olds performed well on context dependant semantically related lists over dissimilar lists, but no difference was found in recall between the broader categories that were context independent semantically related lists and semantically dissimilar lists. However the nine year old age group was superior for this latter task. This latter finding Monnier and Bonthoux (2011) propose could occur due to age related increases in knowledge, supporting improved discrimination within semantic categories.

The episodic buffer has also been implicated in four and five year old children for sentence recall tasks (Alloway, Gathercole, Willis, & Adams, 2004), and five and six year old children for forgetting chunks of learning episodes in the classroom (Gathercole, Lamont, & Alloway, 2006).

Summary

There are developmental increases in verbal and visuo spatial STM and WM across age groups from 4 to 15 years in typically developing children. Domains for verbal and visuo-spatial storage are shown to be separate but controlled by a domain general central executive resource. Research has shown that increases in WM maybe due to: familiarity with the information presented, more efficient information processing, and rehearsal strategies being employed. Furthermore rehearsal of information in children does not reliably begin before the ages of seven or eight years of age. Prior knowledge of word forms and sounds assist in recall tasks for verbal information and increases developmentally as knowledge is acquired. There is also evidence that as children develop they begin recoding visual information into a phonological form for rehearsal purposes. What is important to remember alongside developmental increases in WM, is that there is large individual variation within age groups.

The reviewed research has demonstrated that WM is important for storage and processing of information and is critical for day to day activities and tasks. This is highly likely then to affect the important day to day activity for children of going to school and learning new information in various subject areas such as literacy and numeracy. As will be illustrated in the next chapter, WM is important for the storing and processing of new information in order to do well in school curriculum subject areas.

Chapter 3

Working Memory: Association with Learning, Academic Attainment, and Behaviour

Learning and Academic Attainment

As previously mentioned development of WM is stable from ages 4 - 15 years, although there is considerable individual variation (Alloway, 2007). This variation will reflect in the child's capacity to acquire skills and knowledge and is particularly relevant to the school environment for children. Optimal WM functioning underpins learning and assists in sustaining focus in learning situations (Holmes, Gathercole, & Dunning, 2009). Accordingly WM is important to learning areas such as numeracy and literacy (Alloway & Alloway, 2010; Alloway, Gathercole, Kirkwood, & Elliot, 2009a; Alloway & Passolunghi, 2009; Bull & Scerif, 2001; Cain, Oakhill, & Bryant, 2004; De Jong, 1998; De Stefano & Le Fevre, 2004; Gathercole & Pickering, 2000; Nevo & Breznitz, 2011). The first section of this chapter will summarise studies that have investigated WM in relation to these important abilities. This section is followed by research that looks specifically at children with low WM, their WM profiles, and academic achievement in the areas of numeracy and literacy. Following this is a section devoted to WM behaviour in the classroom and at home.

Some of the studies reviewed address specific literacy skills such as: reading comprehension, language comprehension, fluency, spelling or writing. Some use the umbrella terms of *English* or *reading* to refer to a number of literacy skills examined collectively, (i.e., all or some of the skills just mentioned). The specific skills looked at will be specified where appropriate. Similarly numeracy/maths skills in some studies have been specifically investigated, (e.g., number operations, strategies, number knowledge, and quantity discrimination). Yet in most others the umbrella term of maths is used to describe general skills of maths, as mentioned, with no explanation. Specific skills are specified where appropriate. When using the terms literacy/English and numeracy/maths throughout the current study unless specified, the terms will be referring to broad areas of skills.

Literacy. Verbal STM and WM are consistently found to be related to literacy skill acquisition in children as the following research will illustrate. Daneman and Merikle (1996) undertook a meta-analysis investigating WM tasks as predictors of language comprehension ability and found from their review of 77 studies that verbal WM tasks, (e.g., listening recall), to better predictors of comprehension than verbal STM tasks alone. They also found that verbal maths WM tasks, (e.g., backward digit recall), to be good predictors of language comprehension. In relation to the predictive ability of STM tasks alone on language comprehension, verbal STM tasks (e.g., word span) were better predictors than maths STM tasks, (e.g., digit span forward).

Leclercq and Majerus (2010) state that verbal STM skills are important for developing vocabulary, (i.e., the phonological loop must first efficiently store and rehearse the word or phonological information for transfer and representation into LTM). Leclercq and Majerus (2010) found that verbal STM serial order tasks were best predictors of vocabulary one year later in a group of four year old kindergarten students. Alloway & Alloway (2010) conducted a longitudinal study of children still in kindergarten and then again 6 years later, on; verbal WM measures, fluid and crystallised intelligence measures, and literacy measures: oral reading, reading comprehension, and spelling. They found that verbal STM and WM was significantly related to literacy at both time points and accounted for a significantly higher proportion of variance than IQ.

Berninger et al. (2010) also found that word-level verbal WM predicted all outcomes in literacy: reading, reading comprehension, handwriting, spelling, and written expression at year three, but by year seven it predicted only reading and spelling outcomes. They found at year seven, sentence-level verbal WM to a better predictor of reading comprehension, stating that word-level WM appears to be important when children are developing reading and writing skills. However once they become more skilled and adept in literacy skills more complex WM measures such as sentence level tasks may better predict literacy outcomes.

Similar findings were reported by Cain, Oakhill, and Bryant (2004) who tested children with average reading ability at three time points, ages: 8, 9, and 11 years. Verbal WM was measured by a sentence span plus processing task and a digit sequence span plus processing task. Sentence span was significantly correlated to reading comprehension at each time point. Furthermore, after controlling for other contributors to reading comprehension such as: verbal skills, reading skills and vocabulary, they found that verbal WM was significantly correlated.

Maths. Alloway and Passolunghi (2011) found that verbal and visuo-spatial WM predicted maths scores in seven year olds and were specifically important in single digit addition and subtraction problems, and number ranking. In the same group visuo-spatial STM predicted quantity discrimination and number production. However in a group of eight year olds only visuo-spatial STM scores predicted maths scores, specifically: single digit addition, subtraction, and number ranking. Similarly, in a longitudinal study of children from the ages of 4 to 8 years, Bull, Espy, and Wiebe (2008) found that the best predictor of maths achievement at entry to primary school to be visuo-spatial STM. There were also smaller but significant contributions from verbal STM and verbal WM. By the time these children were tested at the third time point: 7 to 8 years, the best predictor of maths achievement was visuo-spatial WM. Additionally, they found other executive functions such as: attention shifting, inhibition, and goal planning to be important to maths achievement.

Krajewski and Schneider (2009) alternatively found an indirect relationship between visuo-spatial WM and maths achievement, but they were specifically looking at number quantity competencies only. They found that this relationship was mediated by quantity to number word linkages, and that the finding though indirect is important when the representation of quantities are non-verbal. They emphasise that deficits in the visuo-spatial sketchpad at a young age may show up as problems starting with linking number words and digits to quantities, therefore identifying and remediating this problem may help in avoiding later maths difficulties.

In a study of word maths problem solving amongst school children in years 3, 4, and 5, Zheng, Swanson, and Marcoulides (2011) found that WM abilities explained the relationship between age and increases in problem solving abilities. Furthermore all three WM components: phonological loop, visuo-spatial sketchpad, and the central executive, were significant predictors of word-problem solving abilities, with the central executive having the highest effect size. They found though, that the relationship between WM and problem solving accuracy was mediated by reading skills and calculation competence, implicating the importance of LTM contributions through the central executive.

Explanations for the correlation between visuo-spatial memory and maths skills have been likened to visuo-spatial memory being a mental blackboard or workspace on which calculations, number representations, place values, and column alignment can be performed (Geary, 1990; McLean & Hitch, 1999). If visuo-spatial memory is low, similarly the room on the blackboard is not enough to hold all the relevant mathematical information when needed (Heathcote, 1994; as cited in Alloway, 2006). It appears that as children develop, all components of WM are critical to building skills in literacy and numeracy. The pattern of results appears to be similar in real world settings, when national curriculum assessments have been used to explore these same relationships.

***WM and national curriculum assessments*.** Gathercole and Pickering (2000) used data from national school assessments employed in the British education system and WM measures to explore this relationship in a group of seven year old primary school children. They found that low scores on measures of verbal WM as well as measures of visuo-spatial STM successfully differentiated children that were failing to achieve expected levels of attainment in English: reading comprehension, and spelling; and maths from children that were achieving at normal levels. Gathercole and Pickering (2000) also found that WM deficits were generally greater for children with low attainment in maths and a combination of low maths and English.

Gathercole, Pickering, Knight, and Stegmann (2004) explored this relationship further, again using national curriculum measures and verbal WM measures with a group of 7 to 8 years olds and a group of 14 – 15 year olds. For the younger group, WM scores increased across low to higher achieving groups in both English: reading comprehension, and spelling; and maths curriculum areas of which were both highly correlated to each other. The verbal STM task of digit recall and verbal WM task of listening recall were highly correlated to both English and maths and the non-word recall task was significantly associated with English only. Furthermore, results of a discriminant functional analysis revealed that listening recall and non-word recall tasks were best at discriminating low achievers from the high achievers in curriculum areas.

The pattern of results for the older age group revealed that curriculum areas of English and science and maths were moderately correlated with each other. Maths and science were highly correlated with each other as well as three WM tasks: listening recall, backward digit recall, and wordlist matching. Links between the curriculum area of English and the WM tasks were much lower but still significant. Group membership: low, average, or high was best discriminated in maths between low and average achievers with backward digit recall. Science was best discriminated by scores in the listening recall task. There was no functional significance reached for scores between groups in English (Gathercole, Pickering, Knight et al., 2004).

Gathercole, Pickering, Knight et al. (2004), state that weaker relationships between verbal WM and English achievement in the older age group could well be a reflection of the fact that English tests of achievement in the school curriculum at seven years of age directly centre on literacy skills: reading comprehension, spelling, and reading. Whereas the English assessment in the older age group focus on the ability to interpret a written passage, and assesses literacy skills that demand more complexity and understanding of deeper meanings.

St Clair-Thompson and Gathercole (2006) found both components of WM: verbal, and visuo-spatial to be associated with attainment in both English: reading, spelling, and writing; as well as maths in a sample of 11 year old children. On a closer analysis they found that there was a significant correlation between verbal WM and English, and also a significant correlation between visuo-spatial WM and English. They surmise that the latter association was found because of a greater draw on the more general component of the central executive by visuo-spatial tasks.

Jarvis and Gathercole (2003) investigated the relationship of WM tasks to academic achievement at school in the subject areas of English: reading, writing, and spelling; maths, and science. Two groups of children were assessed with mean ages of 11 years and 14 years. In relation to English and maths achievement maths achievement was best predicted in the 11 year old age group by performance on the verbal WM task, listening recall. In the 14 year old age group English achievement was best predicted by scores from two verbal WM tests: listening recall, and backward digit recall. Maths achievement was best predicted by backward digit recall and two visuo-spatial WM tests: spatial span, and odd one out.

Summary

Both verbal STM and WM ability are important for predicting literacy achievement across age groups ranging from 4 to 15 years. It appears that verbal STM is more important for younger children as literacy skills are developing. Verbal STM is more predictive of a wide range of literacy skills at those age groups, inclusive of: reading, reading comprehension, and vocabulary. As children develop, verbal WM scores predict literacy achievement as it seems that more complex memory measures are better equipped to detect more advanced literacy skills. It also appears that visuo-spatial STM and WM is important at predicting maths competency in children. In some studies verbal WM was also found to be important. Researchers were also careful to point out that other skills important to maths achievement were other executive skills such as: attention, shifting, and planning; as well as reading skills, and calculation skills. These may also depend on what subset of skills within the topic area of mathematics is being assessed.

Low WM

Identifying prevalence statistics of low WM is difficult. A search of the databases revealed that most studies investigating comparisons of children with low WM to other groups select a smaller sample of children with low WM scores from larger study groups and have not reported prevalence in these smaller samples. The only example found where figures were given was a study by Alloway, Gathercole, Kirkwood, and Elliot (2009a). They screened 3,189 children aged 5 to 6 (N = 1470), and 8 to 9 (N = 1719), using two subtests of the Automated WM Assessment (AWMA, Alloway, 2007). Of these children 361 or 11% were found to be performing at or below the 10^{th} percentile for their age. One of their aims was to investigate academic progress of children with low WM in reading: reading, reading comprehension, and spelling; and maths.

Findings from Alloway, Gathercole, Kirkwood, and Elliot's (2009a) study, were that across both younger and older group's, performance was lower in all WM tasks, with greater deficits in WM tasks, over STM tasks. Findings that both verbal and visuo-spatial WM scores were lower, fits with a domain general view of WM, in that, children with low WM draw on more executive resources when completing demanding tasks. Percentages of children that scored one standard deviation below the mean (*M* = 100, *SD* = 15) in any WM component were as follows: 95% verbal WM, 71% visuo-spatial WM, 52% and 50% for verbal and visuo-spatial STM respectively. The percentage for differing combination WM scores that fell one standard deviation below the mean: 66% for both verbal and visuo-spatial WM, 49% for both verbal STM and WM, and 23% scored below 85 in all four components of WM.

With respect to the areas of learning in maths and reading, WM scores provided the largest percentage of variance in predicting both maths and reading scores, even when cognitive ability was accounted for. If prevalence of reading and maths difficulties are looked at in terms of children with low WM, Alloway, Gathercole, Kirkwood, and Elliot (2009a) found in their samples of children aged from 5 to 6, and 8 to 9, that 68% of the older age group were failing at reading assessments whilst 71% were failing at maths.

The younger age group fared slightly better with 63% failing to achieve in reading and 65% failing to achieve in maths.

Alloway, Gathercole, Kirkwood, and Elliot (2009a) suggest that as children progress through schooling and as school tasks become more complex and autonomy of learning is promoted, if WM deficits are present, academic attainment falls behind and children fail to progress. A previous study by, Gathercole and Pickering (2000) obtained a similar result in a sample of seven year old children.

In a study investigating patterns of school readiness, though not directly measuring WM, Sabol and Pianta (2012) found that a small group of children who scored low on verbal WM tests at four and a half years of age had the highest level of teacher reported socio-emotional problems in their first year of primary schooling. This group also scored significantly below other groups on measures of reading: letter-word identification, and reading comprehension, and maths: calculation, and applied problems.

Engle, Carullo, and Collins (1991) studied word span and reading span, and their relationship to direction taking, similar to directions that would be given in a classroom on a daily basis. This study gave some idea of how many chunks of information could be stored, processed, and acted up on in a classroom of children that were in years: 2, 4, and 7. They found for the low span groups across the age groups, that as directions became more complex, these children had more difficulty in contrast to the high span group. Engle, Carullo, and Collins (1991) suggest that smaller chunks of information will benefit younger groups and children with low WM, so that tasks can get accomplished.

WM and Behaviour

Behaviour relating to WM can be viewed as children's performance on WM tests or the correlation between scores on WM tests and other measures that purport to reflect a measure of performance of other qualities. These other qualities have been discussed as performances on tests of achievement or learning so far. The next section of this chapter focuses on overt observable behaviour that others can see and report up on, that may give an indication of what WM may look like in settings that are important to learning success, and home life. Therefore the first part of this section will be devoted to reviewing studies that have investigated WM and classroom behaviour. The second part will review research investigating WM and behaviour at home.

Behaviour in the classroom – rating scales. Research investigating classroom behaviour and its correlation with WM is sparse (Gathercole, Lamont et al., 2006). WM and its behavioural expression has not generally been investigated as the focus of research, rather it is generally examined secondary to a core deficit such as *attention deficit hyperactivity disorder* (ADHD) for instance. In the few studies that have focused on WM, and the ones that have considered it secondary to a primary disorder, classroom behaviour is typically captured using rating scales filled in by teachers that have some experience in observing the children they have rated (Alloway, Gathercole, Holmes et al., 2009; Gathercole, Alloway, Kirkwood et al., 2008; Kofler et al., 2011). Following, is a summary of the few studies that have compared WM with behaviours observed in the school setting.

Alloway, Gathercole, Holmes et al. (2009) and Gathercole, Alloway, Kirkwood et al. (2008) have compared WM scores of children with teacher ratings of classroom behaviour using the *Behaviour Rating Inventory of Executive Functioning* (BRIEF[1], Goia, Isquith, Guy, & Kenworthy, 2000) and the *Conners Teacher Rating Scale* (CTRS [1], Conner, 2005; as cited in Alloway, Gathercole, Holmes et al., 2009). The studies investigated a younger group, aged 5 to 6 years, and an older group, aged 9 to 10 years and found similar results. The older group of children with low WM obtained higher ratings on the BRIEF subscales of: initiation, WM, and planning/organisation. The

[1] The BRIEF is a questionnaire consisting of 86 statements of problem behaviours divided into eight subscales; inhibition, shifting, emotional control, initiation, planning and organisation, organising material, monitoring and WM. The teacher must rate each statement according to the frequency of the behaviour; never, sometimes, often (Goia et al., 2000). The CTRS is a questionnaire that is used specifically to identify attentional problems and ADHD based on observed school behaviours. It consists of 28 brief statements divided in to four subscales; oppositional, cognitive problems/inattention, hyperactivity, ADHD index. Teachers rate each statement from the response choices of; not true at all, just a little true, pretty much true, very much true (Conner, 2005; as cited in Alloway, Gathercole, Holmes et al., 2009).

younger group with low WM obtained higher ratings on the subscales of: emotional control, initiation, and WM. The only subscale where clinically significant scores were not obtained was in the organising materials subscale.

With regard to ratings obtained on the CTRS, 79% of the younger children with low WM, and 70% of the older group with low WM scored in the atypical range for the cognitive problems/inattention subscale and 66% of the younger children scored in the atypical range on the ADHD subscale. These children were characterised as having; poor attention, and being very distractible, failing to monitor the quality of their work, and having reduced problem solving ability. Gathercole, Alloway, Kirkwood et al. (2008) put the explanation of these results down to WM overload, and decay of information from WM. Alloway, Gathercole, Holmes et al. (2009) described the children as: inattentive, with poor attention spans, distractible, forgetful whilst doing tasks and when given instructions. Furthermore, the children did not complete tasks, made mistakes in writing, and were poor problem-solvers.

Alloway, Gathercole, Kirkwood, and Elliot (2009a) found that 67% of their low WM sample with a mean age of 8.8 years, obtained high ratings of problem behaviours on the *Working Memory Rating Scale* (WMRS [2], Alloway, Gathercole, & Kirkwood, 2008). Alloway, Gathercole, Holmes et al. (2009) obtained a similar percentage of cases with the WMRS when investigating behavioural differences between boys with ADHD and low WM and controls with an age range of 8 to 11 years. Sixty five percent of the low WM sample was correctly classified with WM problems. However, Alloway, Gathercole, Kirkwood, and Elliot (2009b) caution that motivation and boredom of the child may influence teacher ratings.

[2] The WMRS is a 20 item WM behaviour rating scale consisting of 20 questions, with four response options; not typical at all, occasionally, fairly typical, and very typical. Examples of the types of questions used are; he/she loses track of where they are up to in an activity with many steps, instructions need to be repeated, does not finish activities, needs repeat reminders in written activities (Alloway, Gathercole, & Kirkwood, 2008).

Behaviour in the classroom – observations. Gathercole, Lamont et al. (2006) bridged the gaps between scores on WM tests, tests of achievement, and behaviour rating scales, by implementing an observational study in the classroom. This was carried out to identify what strains are put on WM in the classroom environment and what problems children with low WM encounter during everyday classroom activities. Three boys were studied that were assessed using various WM measures that tested the phonological loop, visuo-spatial-sketchpad, and the central executive. They were observed over a period of four days each.

The main categories of memory failure between the boys were; forgetting instructions, especially if the instruction was long and out of the ordinary. The inability to deal with concurrent processing and storage demands was another, for example, a literacy development task would be to memorise a sentence and count the words in it before writing it. One of the boys could not remember the sentence, isolate the words, or count the words without help from his teacher. Another category of memory failure was losing track in complex tasks, for instance, in sentence writing some of the words would be forgotten and position in the sentence would be lost, resulting in: omission, repetition, or intrusion of new words, consequently tasks were abandoned. Episodic forgetting was another category, for example information that was learned earlier in the day or earlier in an activity was forgotten.

Other behaviours that were commonly observed across the group were: being reserved/not offering information in classroom discussions, using basic strategies or apparatus rather than more efficient ones to help with tasks even though the formerly mentioned strategies may take longer to complete a task. These children also appeared to have no overt behaviour problems and seemed well adjusted socially (Gathercole, Lamont et al., 2006). Conversely, CTRS questionnaires filled in by their teachers indicated that inattentive behaviours were apparent in two of the boys. The conflict between observation and teacher ratings could have been due to factors such as: having an unfamiliar/new observer in the classroom, the observation was taken over a very short time frame, teachers would have been more familiar with the children and spent longer periods of time with them.

Behaviour in the home/out of the school environment. A search of the databases using search terms such as: behaviour, ratings, child, WM, low WM, home, and environment revealed only one such study by Lui and Tannock (2007). However there were studies relating to behaviour ratings of children with primary deficits such as: ADHD, learning disorders, and *traumatic brain injury* (TBI). These studies are reviewed along with the Lui and Tannock's study as they may be helpful at giving an insight into the abilities of parents at being able to identify problem behaviours in children that are experiencing difficulties.

Lui and Tannock (2007) found evidence of a relationship between WM scores and inattentive parental ratings in a randomly selected community sample of 7 to 12 year olds. However, this finding did not extend to WM scores and hyperactive/impulsive ratings. Lending support for the idea that WM depends on attentional control and additionally, is apparent in overt behaviour that can be observed by others. They also found a gender difference; in that parents rated boys more hyperactive than girls, and an age difference; younger children were rated more inattentive and hyperactive than older children.

Parents have been found to rate less executive functioning impairment than teachers in children with ADHD (Mares et al., 2007, Mitsis et al., 2000). These authors suggest that this maybe because home life is more flexible, tolerant, and less demanding on WM, whilst school work and learning is more demanding and focused on skills that rely on problem solving, planning, and organising. These two alternative environments may account for the discrepancy in findings. Alternatively, Joyner, Silver, and Stavinoha (2009) found that parental ratings of executive function in their children with ADHD was related to the degree of stress they feel at parenting their children. Interestingly, Joyner et al., (2009) found no significant differences in comparisons of ratings between teachers and parents, this comparison helped account for any bias in parent ratings due to stress.

With regard to brain injury, the BRIEF is a useful tool for identifying behavioural symptoms associated with frontal lobe injury and distinguishing this group from other brain injuries of a more diffuse nature (Anderson, Anderson, Northam, Jacobs & Mikiewicz, 2002). Conklin, Salorio, and Slomine (2008) found that parents of children that have suffered a TBI rated their children as having more impaired executive functions on the BRIEF if the injury was received more than a year prior to rating, and if the injury was moderate to severe.

Summary

Behavioural ratings of children with low WM have highlighted behavioural and executive functioning deficits compared to typically developing controls. Behaviours commonly rated as difficulties are: attention, problems with planning, problem solving, and monitoring work. These children are said to be: distractible, to have cognitive difficulties, and display problems with emotional control especially in early school age groups.

Behaviour rating scales have been useful in highlighting behavioural difficulties in groups of children where WM function is compromised, (e.g., children with ADHD-I & C, TBI, and low WM). Some research has found differences in symptom reporting when there are more than one rater and in different environments, (perhaps because different environments exact differing degrees of WM and executive functioning).

An observational study of classroom behaviour gives more indepth details of WM problems in children, and highlights that children with low WM forget instructions especially for complex tasks, have trouble staying on task, and therefore needing regular reminders. Low WM children also choose to use simple more time consuming memory strategies to assist with tasks rather than using more efficient strategies which may appear, on face value to the child, to be more complex.

Chapter Summary

Research has revealed that WM is an important building block for learning information that is important for literacy and numeracy acquisition. Researchers have found that STM is more relied upon when children are young and acquiring skills in literacy and numeracy. But as these skills develop, WM is more predictive of learning achievement as literacy and numeracy learning becomes more complex. Research investigating behaviour has revealed that children with deficits in WM display certain characteristics at school such as: attention problems, problem solving difficulties, and forgetting information and instructions given. Research, though scant on behaviour in the home is conflicting, it has revealed that parents rate children with WM difficulties as more inattentive and having deficits in executive functioning, other researchers found parents do not rate their children's behaviours as different. This leads onto the next chapter which discusses specific disorders and conditions and their relationship with WM, academic achievement, and behaviour.

Chapter 4

Working Memory, Special Populations, and WM Training

Children enter school from all walks of life and backgrounds. They may have been impacted by environmental events, and/or inherited genetic characteristics. These variables all impact on WM and learning which their educator and/or parent may or may not be aware of, or are yet undiagnosed. This chapter will cover some of the conditions and syndromes that occur during childhood which are associated with impairments in WM and learning, and which present challenges for both educators and children. Therefore, reviewing this research is essential as it may provide clues as to why some children have difficulties with WM and academic attainment and give an etiological basis for some of these difficulties. Furthermore, the review in this chapter highlights that some of the disorders have specific patterns of deficit in WM, which if revealed can be remediated or compensated for with individual learning programmes.

Each of the following sections will briefly cover key characteristics of a disorder, the prevalence statistics if known and a review of research demonstrating links to WM. Not all conditions and disorders relevant to studies of WM will be covered such as the more pervasive disorders, (e.g., intellectual disabilities, or autism) because the current research is focussed on otherwise normally developing children in mainstream schooling who may be having difficulties or challenges with learning progression. Finally, there is a brief section that reviews research on WM training.

Learning Disorders

Learning disorders are characterised for individual children by scores on standardised tests of achievement that are considerably lower than what would be expected for their age, level of schooling, and level of intelligence. The learning disorder must interfere with their academic achievement or daily tasks that necessitate reading, writing, or maths skills. To some extent language disorders may co-occur with reading and maths disorder (American Psychiatric Association, 2000). In this section the focus will be on reading, maths, and language disorders.

Reading Disorder. The prevalence of reading difficulties in school children in English speaking countries is between 4 to 8% (Hulme & Snowling, 2009). Factors that have an influence on this disorder in differing degrees are: genetics, mother's education level, schooling, and exposure to books at home (Hulme & Snowling, 2009). Children with reading impairments have difficulties with phonological awareness, coding, and the ability to quickly retrieve phonological information from LTM (Torgesen & Burgess, 1998).

Phonological awareness refers to an individual's awareness of a languages sound structure of spoken words. Phonological (verbal) STM has been found to be significantly associated with reading achievement in younger readers as reading skills are emerging (Wagner & Muse, 2006). More importantly, studies have found WM scores for reading impaired children to be lower than those that are not impaired (Gathercole, Alloway, Willis & Adams, 2006; Siegel & Ryan, 1989; Swanson, 1999; Swanson & Berninger, 1995).

Gathercole, Alloway et al. (2006) found dissociation between verbal STM and WM in a group of reading impaired school children with a mean age of nine years. The group had low to average verbal STM scores whilst their verbal WM scores were significantly impaired and strongly associated with their low reading scores. They found that this relationship was not mediated by IQ level, verbal abilities, or phonological awareness, possibly due to the group being at an age where such skills were already mastered. This group also scored very low on visuo-spatial STM measures, unfortunately as visuo-spatial WM was not assessed no conclusions could be reached in relation to this relationship.

Swanson and Berninger (1995) also found that WM scores were lower than age matched controls in a group of reading disabled children and further, that the relationship between WM scores and reading comprehension remained after reading recognition was taken into account. In addition, a dissociation of verbal WM components was found, in that; reading disabled children who had low comprehension skills had low verbal WM scores but normal verbal STM scores. Conversely, children with low reading recognition skills had low verbal STM scores but average verbal WM scores. Not surprisingly, the children with lower skills in both reading recognition and comprehension had low scores in both verbal WM components.

In a study investigating which modality of WM tasks are sensitive to differing populations of learning impaired children Siegel and Ryan (1989) found that reading impaired children performed poorly on language related tasks, which were aurally delivered sentence span tasks. They also performed poorly on counting related tasks, which were visually presented counting span tasks on provided cards. This finding was consistent across age groups 7 to 8 years, 9 to 10 years, and 11 to 13 years, although there were developmental increases in scores. This leads to the conclusion that difference in presentation modality of the material has no difference to recall in reading disabled children (Siegel & Ryan, 1989). Both tasks mentioned are commonly known as verbal WM tasks presented in different modalities.

In contrast to the Gathercole, Alloway et al.'s (2006) finding of low visuo-spatial STM, there are researchers who have found visuo-spatial memory to be relatively intact in these children. For instance Katz, Shankweiler and Liberman (1982), Liberman, Mann, Shankweiler, and Werfelman (1982), and Swanson (2006) have found that visuo-spatial STM is only impaired in reading disabled children if the stimulus presented can be recoded into verbal labels, (e.g., line drawings of animals). If the stimulus is not readily recoded, (e.g., nonsense line designs, or are unfamiliar photographs) then performance did not differ from controls. The tasks in these experiments were recognition based.

Gould and Glencross (1990) obtained a similar finding using a visual STM recall task. The reading impaired children performed just as well as controls in a task where they had to watch the experimenter tap a sequence of blocks, and then tap the blocks in the same sequence. Gould and Glencross (1990) summarised that if the visuo-spatial components of WM are relatively intact in reading impaired children, then enhancing learning through this modality may be of benefit.

Table 4.1 summarizes the aforementioned research on WM and reading disorder.

Table 4.1

Identified WM Deficits in Children with Reading Disorders

Authors	Sample	Deficit/Problem Area
Gathercole, Alloway, et al. (2006)	6.5 – 11 year olds	Verbal WM, visuo-spatial STM. Low average verbal STM.
Martinussen & Tannock (2006)	9 year olds	Verbal & visuo-spatial WM, verbal & visuo-spatial STM.
Siegel & Ryan(1989)	7 – 13 year	Verbal WM
Swanson & Berninger (1995)	11.5 years mean age, & 13.5 years mean age	Verbal STM, verbal WM

Maths Disorder. Impairments in maths ability appears as problems in one or many areas of mathematics, from simple arithmetic calculations such as adding and subtracting to more complex areas like algebra and geometry (Passolunghi, 2006). Prevalence of maths disorders is difficult to ascertain as the majority of studies on learning disorders encompass all subtypes, with little separation into specific subtypes, however estimates of one percent have been postulated in children attending school (American Psychiatric Association, 2000). Earlier estimates have placed this number higher at six and a half percent (Gross-Tsur, Manor, & Shalev, 1996).

WM has been implicated in emerging maths acquisition of counting, with low scores being associated more with basic finger counting strategies over more complex ones. Geary, Hoard, Byrd-Craven, and De Soto (2004) postulates that this is because such simple strategies are not too taxing on the WM system. Different studies have found more generally that both verbal and visuo-spatial WM components are deficient in maths impaired children (McLean & Hitch, 1999; Swanson & Bebe-Frankenberger, 2004). Some have found no contribution from phonological STM components (McLean & Hitch, 1999).

Swanson and Beebe-Frankenberger (2004) found that verbal WM was significantly associated with problem-solving in maths impaired children, but they found that it was not the sole contributor. Other skills such as reading ability and processing speed were also important, and they emphasised the importance of the central executive's ability to access information in LTM in demanding tasks.

McLean and Hitch (1999) found that WM tasks measuring visual, spatial, and verbal contributions to be deficient in a maths impaired group, employing tasks such as verbal and visual trails, and a missing item task. On closer inspection it seemed that low scores for both trails tasks indicated a deeper problem with switching plans to finding correct solutions. Problems with the missing item task, which requires the child to mentally hold information in mind whilst simultaneously accessing and manipulating already learned information, may point to problem interactions with LTM, or problems with decaying of information for basic number facts occurring before long term memories for them can be formed.

When testing verbal WM of children with a maths disorder, it is important to include tasks that employ components that investigate possible differences between verbally presented and numerically presented tasks, (e.g., different modalities). Siegel and Ryan (1989) found in their sample that maths impaired children had no difficulty with an aurally delivered verbal sentence WM task, but had problems with a verbal WM counting recall task which was visually delivered. The task involved counting all the yellow dots in a field of yellow and blue dots on cards. Then relaying back the total count of yellow dots in sequence after the last card is presented. Perhaps the visual nature of the latter task points more to a deficit in visuo-spatial WM, because of the format of the task.

Geary et al. (2009) found that verbal and visuo-spatial STM and verbal WM was deficient in a group of maths learning disordered children who had just started primary school. Swanson (2012) found a similar result for verbal STM and WM, but also found deficiency in visuo-spatial WM in a group of maths disordered teenagers relative to controls. Conversely, Passolunghi, Cornoldi and De Liberto (1999) found no difference in scores between controls and maths impaired children on verbal STM word recall tasks. But they did find differences in verbal WM using listening recall tasks and sentence maths problems. The maths impaired children remembered significantly more irrelevant words and failed to remember significantly less to be remembered words than children with no maths difficulties, in listening span tasks. Passolunghi et al. (1999) surmised that inhibiting irrelevant information from WM could be part of these children's difficulties. They also found these results were consistent in the same children two years later.

Table 4.2 summarizes the aforementioned research and findings.

Table 4.2

Summary of Research on Maths Disorder and WM Difficulties Experienced by Children

Authors	Sample	Deficit/Problem Area
Geary et al. (2009)	6 - 7 year olds	Verbal and visuo-spatial STM, verbal WM
McLean & Hitch (1999)	Mean 7.11 years & Mean 9 years, age groups	Verbal and visuo-spatial WM
Passolunghi et al. (1999)	9.6 years 1st tested - 11.5yrs last tested	Verbal WM
Siegel and Ryan (1989)	9 - 10 yrs & 11 - 13 years	Visuo-spatial STM
Swanson (2012)	14 - 17 year olds	Verbal STM and verbal and visuo-spatial WM
Swanson & Bebe-Frankenberger (2004)	Primary school aged	Verbal WM

Specific Language Disorder. Specific language disorder (SLI) is a communication disorder where language skills are delayed or disordered and not related to any other developmental delays, hearing loss, or emotional and neurological problems. These children may be late to start speaking and when they do, the sound may be unintelligible. Expression of the disorder may depend on its severity and the age of the child, and can include: restricted amount of speech and vocabulary, simple speech used, problems with word finding and learning new words, shortened sentences, and difficulty with the use of verbs (American Psychiatric Association, 2000; National Institute of Deafness and Other Communication Disorders, 2012). Other children with SLI may have difficulty understanding the speech of others. Some children overcome SLI, but for most it is enduring and will have an influence on how well they achieve at school and in their personal lives (Archibald & Gathercole, 2006a). Prevalence rates for specific language disorder vary according to age; under three years of age it is 10 to 15% of children, at school its 3 to 7% (American Psychiatric Association, 2000).

Children with SLI have shown marked deficiencies in phonological STM compared to age matched controls (Archibald & Gathercole, 2006b; Balthazar, 2003; Alloway, Rajendran, & Archibald, 2009; Hutchinson, Bavin, Efron, & Sciberras, 2012). It is believed that children with SLI have difficulties with storage of exact sound representations, making it hard to learn new words and to speak them (Henry, 2012). Children with SLI show consistent and marked deficits in the phonological STM non-word repetition task and as such this task is helpful in assistance of SLI diagnosis (Archibald, Gathercole, 2006b; Gathercole & Baddeley, 1990; Conti-Ramsden & Durkin, 2007).

Word length effects in verbal STM have been found in children with SLI (Balthazar, 2003; Gathercole & Baddeley, 1990), with Balthazar surmising processing speed to be an issue. Both Hutchinson et al. (2012), and Petrucelli, Bavin, and Bretherton (2012) have also found deficits in verbal STM. However, Petrucelli et al. (2012) did not find differences between SLI children and controls in verbal WM but Hutchinson et al. (2012) did. Petrucelli et al. (2012) only used one test to assess verbal WM, where as Hutchinson et al. used three.

In relation to visuo-spatial memory some researchers have found no differences (Alloway, Rajendran et al., 2009; Archibald & Gathercole, 2006c; Henry, Messer & Nash, 2012; Hutchinson et al., 2012; Petrucelli et al., 2012). But there are others that have found these deficits (Marton, 2008; Im-Bolter, Johnson, & Pascual-Leone, 2006; Hoffman & Gillam, 2004). Consequently, results are mixed regarding the implication of deficits in visuo-spatial STM. Differences may be accounted for by developmental age of sample, measures used, modality of measures, and degree of deficit.

Table 4.3 summarizes studies on WM and SLI highlighting which components of WM have been found to be deficient.

Table 4.3

Summary of Research Findings on WM and its Relationship to Children with SLI

Authors	Sample	Deficit/Problem Area
Archibald & Gathercole (2006a)	7 - 11 years old	Verbal STM deficits
Archibald & Gathercole (2006c)	7 - 11 years old	Verbal STM and WM deficits
Balthazar (2003)	7 years old	Verbal STM
Hoffman & Gillam (2004)	9 year olds	Visuo-Spatial STM
Hutchinson et al. (2012)	6 - 9 years old	Verbal STM and WM deficits.
Im-Bolter et al. (2006)	7 - 12 year olds	Visuo-Spatial WM
Marton (2008)	5 - 6.7 years and 8 - 11.2 years old	Visuo-spatial STM deficits
Petrucelli et al. (2012)	5 year olds	Verbal STM deficits.

Summary

Research on children with learning disorders has highlighted that low WM abilities appear to be a feature for these children. Verbal STM and WM appear to be the most impaired components that are related to reading difficulties. Both verbal and visuo-spatial WM appear to be the most deficient in children with maths disorder, although visuo-spatial STM has been found to be deficient also. Verbal STM seems to be the most impaired WM component for children with SLI although verbal WM and visuo-spatial STM and WM have also found to be deficient. As there seems to be a general pattern of deficit according to specific learning disorders, (i.e., deficit in certain WM components), but possible deficits in other components, comprehensive assessment would be crucial to investigate impairment and strengths for possible remediation.

ADHD

ADHD is one of the most common disorders of childhood, occurring in approximately five percent of the population (American Psychiatric Association, 2000). ADHD is characterised by three core features that are developmentally inappropriate: inattention, hyperactivity, and impulsivity. The criteria that warrants diagnosis of ADHD are, at least six symptoms of either; inattention, predominantly inattentive diagnosis ADHD-I; or hyperactivity, predominantly hyperactive-impulsive diagnosis ADHD-H/I; or six or more symptoms of both, diagnosis of combined type ADHD-C. Symptom duration must be for at least six months, onset before seven years of age, in two or more settings. (American Psychiatric Association, 2000).

There are varying theories of ADHD, for instance one view is that children with ADHD cannot successfully cease attending or responding to irrelevant stimuli in the environment (inhibition) (Roodenrys, 2006). More specifically the control of attention rather than the absence of an attentional capacity is seen to be deficient. Barkley (1997) theorises that if behavioural inhibition does not develop typically in childhood, secondary deficits in other executive functions develop, these include deficient: nonverbal WM, internalisation of speech, self regulation of affect, motivation and arousal, and reconstitution. This theory of ADHD implicates WM or at least its link with inhibitory processes as having an unfavourable effect on children with AHDH (Roodendrys, 2006).

WM profiles have generally been found to be lower in children with both ADHD-I and ADHD-C than the normal population (Alloway, Elliot, & Place, 2010; Diamond, 2005; Kofler et al., 2011; Martinussen & Tannock, 2006; Rapport et al., 2009). Other difficulties include: inhibition, processing speed, vigilance, planning, organising and set shifting (Chhabildas, Pennington, & Willcutt, 2001; Mares et al., 2007; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Sustained attention is also found to be deficient in ADHD-C children and to a lesser extent in ADHD-I children. These deficits combined with low WM, influence performance in measures of reading and maths (Alloway et al., 2010; Diamond, 2005; Martinussen & Tannock, 2006; Willcutt et al., 2005).

Westerberg, Hirvikoski, Forssberg, and Klingberg (2004) found that slow processing speed is a problem for some children with ADHD-I, which mentioned previously in chapter two, is correlated with articulation rate and also rehearsal for memory span tasks. This factor also accounts for variances on WM tasks for children with ADHD-I. Working Memory in ADHD-I children may be further taxed because these children frequently have difficulties with auditory processing of information. Mc Innes, Humphries, Hogg-Johnson and Tannock (2003) suggest that these children then may have difficulties with comprehension of verbal classroom instructions.

Roodendrys (2006) says that research findings on ADHD populations and WM are often inconsistent as to where the specific deficiency in WM may be (which WM component). He says this is because between differing studies: ADHD subtypes are not specified, there are differing origins of sample selection (community/mental health services), medication of participants is used/not used during studies, and comorbidity with other disorders. All these differing variables may have differing effects on results found.

Table 4.4 summarizes studies that have specifically examined WM in children with ADHD and found components of WM that present difficulties for them.

Table 4.4

Identified WM Deficits in Children with ADHD

Authors	Sample	Deficit/Problem Area
Alloway et al. (2010)	9 year olds	Verbal & visuo-spatial WM. Verbal & Visuo-spatial STM. Performed poorly on reading and maths measures.
Kofler et al. (2011)	8 - 12 year old boys	Verbal & visuo-spatial WM impact hyperactive/impulsive & attentive core symptoms
Mc Innes et al. (2003)	9 - 12 year old boys	Verbal & visuo-spatial WM. Visuo-spatial STM. Correlated with listening comprehension.
Mares et al. (2007)	5 - 15 year olds	Ratings of Central Executive functions explain differences in core symptoms.
Martinussen & Tannock (2006)	7 - 13 year olds	Verbal & visuo-spatial WM deficits independent of IQ, reading and language ability. Also related to ratings of inattention. Visuo-spatial STM.
Rapport et al. (2009)	8 - 12 year olds	Verbal & visuo-spatial WM tasks cause increased physical activity.

Traumatic Brain Injury

The major causes of TBI in New Zealand is motor vehicle accidents (The Brain Injury Association of New Zealand Inc., 2007). The injury sustained can range from mild, moderate, to severe, which is indexed by duration of unconsciousness and amount of memory loss. Barker-Collo (2007) says of school aged children, boys are twice as likely to experience a TBI as girls. As a result of a TBI, symptoms may develop that impair cognitive, physical, and emotional functioning (Bagiella et al., 2010).

There is a high incidence of frontal lobe injuries sustained in TBI which can cause harm to frontal sub-cortical pathways through contusions or diffuse axonal injury (Wilde et al., 2010). As a result WM can be impaired (Levin et al., 2004; Newsome et al., 2008; Anderson & Catroppa, 2007; Conklin et al., 2008; Gorman, Barnes, Swank, Prasad, & Ewing-Cobbs, 2012; Moran & Gillon, 2004, 2005; Moran, Nippold & Gillon, 2006) and as such can have an impact on the academic performance of these children.

Comprehension and verbal WM has been found to be deficient in children with TBI, (Conklin et al., 2008; Moran & Gillon, 2004, 2005; Moran et al., 2006). Gorman et al. (2012) found verbal STM and verbal and visuo-spatial WM to also be deficient in children with TBI. However Gorman et al. (2012) found *socio economic status* (SES), age, and *days to follow commands* (DFC) post injury were significant predictors of WM performance.

However Anderson and Catroppa (2007) found no impairment in verbal and visuo-spatial STM and verbal and visuo-spatial WM five years post injury surmising that WM could have been impaired closer to injury date but had recovered within the five years. However, the TBI group was impaired on a verbal learning task comprising of a list of 16 words which were given to the groups over four trials and one interference trial. A closer analysis of the task was made by dividing the performance by injury severity.

Performance on the first two trials of the verbal learning test was not significantly different between groups, but significant differences were evidenced from the third and fourth trials, with the largest disparity between controls and severe TBI groups. This result highlights that auditory information is shown to be processed immediately and learning does increase but at a rate that is slower than normal with successive repeat episodes. This result has implications for classroom learning of children that have suffered moderate to severeTBI not only in recent history but also in the distant past.

Children of early gestation and low birthweight

Mention is made of this group of children as children born *very pre-term* (VPT) may have deficits in WM despite normal intelligence and parents may or may not be aware that these problems can arise as a result of difficulties that accompany very preterm births. Children that are born VPT are at risk for: cerebral palsy and significant cognitive impairment (Marlow, Wolke, Bracewell, & Samara, 2005), inattention and impulsive behaviour (Mulder, Pitchford, & Marlow, 2011), impaired learning (Rose & Feldman, 1996; Woodward, Edgin, Thompson, & Inder, 2005), visuo-spatial STM/WM deficits (Luciana, Lindeke, Georgieff, Mills, & Nelson, 1999; Vicari, Caravale, Carlesimo, Casadei, & Allemand, 2004), maths difficulties (Isaacs, Edmonds, Lucas, & Gadian, 2001), and verbal WM problems (Fraello et al., 2011).

Verbal STM and WM. In a sample with an age range of 9 to 10 years and a mean gestational age of 27.6 weeks, Mulder et al. (2011) found that lower scores on two verbal WM tests and processing speed tasks were related to inattentive and overactive/impulsive behaviours as rated by teachers, and only overactive/impulsive behaviours as rated by parents. Although academic achievement of this group was not investigated, interpretation of these results suggested that VPT children are at risk of learning deficits in the classroom and home.

Fraello et al. (2011) failed to find a significant difference between VPT children and controls tested at 12 years of age on two verbal STM tests: digit span forward, and non-word repetition, or the verbal WM task: digit span backwards. However once processing and storage demands in WM were increased by requiring verbatim recall of sentences with explanations of concepts and directions, performance by the VPT group dropped significantly. This finding may assist to understand learning deficits where WM impairment impinges on efficient encoding into LTM storage for these children (Fraello et al., 2011).

Visuo-spatial STM and WM. Vicari et al. (2004) found that their young group of VPT children, 3 - 4 years old, performed significantly worse than controls on a visual-spatial WM task. Results revealed that as storage and processing demands increased performance became worse. Vicari et al. (2004) surmised that lower visual-spatial scores were related to brain injury associated with preterm birth. The pattern of results found by Vicari et al. (2004) appeared to be similarly found in older cohorts. Luciana et al. (1999) found 7 to 9 year olds performed poorly on: tests of psychomotor speed and accuracy, spatial STM, visual pattern recognition, spatial WM, and planning and problem solving. They found performance dropped significantly in WM tasks as WM load increased, and that memory strategies were less likely to be used, and if they were they were often abandoned. Furthermore, they found that neonatal illness associated with premature birth was predictive of WM scores. Rose & Feldman (1996) also found in an 11 year old group that recognition was more deficient than controls, as was visuo-spatial STM and WM. Again as memory load was increased, performance declined.

Trauma and mood

Mood. Negative emotional states can also have a negative effect on executive functioning inclusive of WM (Brookes, Iverson, Sherman, & Roberge, 2010; Grimley, Dahraei, & Riding, 2008; Günther, Holtkamp, Jolles, Herpertz-Dahlmann, & Konrad, 2004) with a flow on effect to academic performance and school tests (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005; Keogh, Bond, French, Richards, & Davis, 2004; Owens, Stevenson, Norgate, & Hadwin, 2008; Roughan & Hadwin, 2011).

Grimley et al. (2008) investigated the relationship of WM, cognitive style, and anxiety. They found that higher WM scores were significantly related to low anxiety or the absence of it. They also found that the children who had a cognitive style that demanded a higher processing load also had lower scores on the WM task assessed. Therefore children with low WM and a high processing cognitive style may have increased levels of anxiety in the classroom where processing demands are demanding and complex. The children in this sample were recruited from schools, and anxiety symptoms were reported by teachers, no clinical diagnosis of anxiety disorders were reported.

However in a clinical sample of children with diagnosed depression or anxiety with no comorbidity, Günther et al. (2004) found no differences on WM or learning scores between all groups: anxious, depressed, or healthy controls. Furthermore, no differences were found between the groups on attentional tasks. Günter et al. (2004) did find however that the depressed sample performed worse after an interference trial was introduced in the memory task and the delayed recall task, hypothesising that memory impairment in depressed children is due more to problems with verbal memory, rather than deficient attention.

In contrast to Günther et al.'s (2004) result relating to attention, Brookes et al. (2010) found clinically depressed children performed significantly more poorly than healthy controls on measures of attention, and to a lesser degree performed more poorly on verbal memory tasks. Similarly Aronen et al. (2005) found that low visual-spatial WM performance was related to teacher rated anxiety and depressive symptoms, especially so in younger children, 6 - 8 years of age. They also found that children with teacher rated behaviour and attention problems performed more poorly on the auditory WM tasks used. Surmising that teachers may have to modify teaching practice with low WM children according to which modality best enhances learning for them.

***Trauma*.** Trauma symptoms are anxiety producing and have been shown to disturb executive functioning (El-Hage, Gaillard, Isingrini, & Belzung, 2006; Navalta, Polcari, Webster, Boghossian, & Teicher, 2006; DePrince, Weinzierl, & Combs, 2009). DePrince et al. (2009) investigated whether familial trauma in the form of exposure to physical and/or sexual abuse or witnessing of such trauma within the family environment affected children's executive functioning more than trauma that was non-familial. For instance, motor vehicle accidents, or natural disasters. DePrince et al. (2009) found that there was a moderate relationship between executive functioning and familial trauma, which remained after potential TBI, anxiety, dissociation, SES, and PTSD was partialled out. Variation to executive functioning scores was made only by dissociation and familial trauma exposure, suggesting that; dissociative symptoms and executive functioning need further investigation. Although DePrince et al.'s (2009) finding between executive functioning and familial trauma is not strong, they suggest that trauma exposure must be considered as a contributor to academic performance in school.

WM Training

As the previous research has highlighted, WM has an impact on children's ability to learn at school. In a class of approximately 30 children five will have WM difficulties and will be progressing inadequately academically (Gathercole and Alloway, 2008). In light of these difficulties some researchers have undertaken studies looking at strengthening WM ability.

Klingberg et al. (2005) found in a group of children with ADHD that computerised verbal and visuo-spatial WM training generalizes to performance on other non-trained verbal and visuo-spatial WM tasks, and an inhibition task after 5 to 6 weeks of training. Furthermore WM improvements were stable at three months after training ended. The computerised programme used and developed by Klingberg et al. (2005) known as COGMED allowed the children to train at home or in school. The computer programme is adaptive so trials adjust in difficulty when each one is successfully completed. The children had to complete 90 trials of verbal and visuo-spatial tasks each training day. Thorell, Lindqvist, Nutley, Bohlin, and Klingberg (2009) found the same reported improvements in trained visuo-spatial WM tasks using a similar programme to COGMED, with their sample of 4 to 5 year old children. They also found that training on visuo-spatial WM generalised to improvements on non-trained verbal WM tasks.

Holmes, Gathercole, and Dunning (2009) also used the adaptive computerised training programme COGMED with children that had low WM with a mean age of 10 years. Over a 5 to 7 week period of training, performance improved on visuo-spatial and verbal WM and visuo-spatial STM, but not verbal STM tasks. Scores in maths reasoning also improved six months later following training. The training did not however increase the groups intelligence scores (Holmes et al., 2009).

WM performance has shown improvement after computerised training specifically directed at enhancing memory strategies rather than direct training on WM tasks.

Such training, however, did not have an effect on standardised reading and maths ability tests for 5 to 8 year old children (St Clair-Thompson, Stevens, Hunt, & Bolder, 2010). St-Clair-Thompson et al. (2010) suggest that ability test formats do not necessarily require WM skills that assist storing and processing information mentally, as test information is usually presented and is available visually during testing. Furthermore they suggest that ability tests rely more on previously learned knowledge, rather than the ability to hold and manipulate information, so WM skill acquisition may not be measureable or apparent in standardised ability tests.

Dahlin (2010) found that adaptive computerized WM training not only significantly improved performance on non-trained verbal WM and visuo-spatial STM and WM tasks, but it also significantly improved reading comprehension after five weeks of training, and the improvements remained 6 to 7 months later. These results were obtained with a group of 9 to 12 year old children with general learning needs and attention deficits.

Summary

These findings are important, firstly, as research has demonstrated that computerised WM training can enhance improvement in WM tasks across a broad range of young age groups. WM training has also generalized in some cases to improvements on reading and maths tests, and the improvements have been detected months after training has finished. WM training therefore, can assist children who are having difficulties in WM, with the benefit that such training may assist them with their learning needs in an academic setting.

Chapter Summary

Children with the disorders and experiences just summarized all show deficits in WM which have been related to learning. Not surprisingly the research on learning disorders and ADHD have shown these groups to have more persistent WM impairment, which has a greater impact on learning in the specific area of deficit, (e.g., maths competence). Children with ADHD have low WM and additional difficulties with attention and hyperactivity which hamper classroom learning. Conditions such as: TBI, mood, and VPT show variability in severity or component of WM deficit. This is possibly influenced by other factors unique to their condition, such as: age at injury, time since injury, accompanying illnesses, and frequency and intensity of experience. If these disorders are identified, then WM can be tested in individual children to ascertain which component(s) of WM are deficient, and which components are intact. Consequently, learning practices can be modified dependent on the intact component to improve learning outcomes for these children. Furthermore, adaptive computerized WM training has shown promising results in improving WM ability and learning.

Chapter 5

The Present Study

The previous chapters have shown that WM is an important memory system that is limited in capacity and is important for storage and processing of information (Baddeley & Hitch, 1974) to enable people to carry out everyday activities. All components: phonological loop, visuo-spatial sketchpad, central executive and episodic buffer are necessary for storage, processing, and integrating information in different forms. In typically developing children, WM increases with age throughout childhood although there is large individual variation (Alloway, 2007). This growth has been explained as: increased efficiency in information processing (Case et el., 1982), the use of rehearsal as children age (Henry, 1991a), and linkages with knowledge in long term memory (Monnier & Bonthoux, 2011; Turner et al., 2004).

WM ability is linked to thinking, reasoning, and underpins learning (Alloway & Alloway, 2010). Variation in WM abilities will have an impact on a child's capacity to acquire skills and knowledge. The reviewed research has shown variations in which components of WM may be impaired in certain populations. Taken collectively the review demonstrates that individual, or combinations of components of WM: verbal STM, verbal WM, visuo-spatial STM, and visuo-spatial WM are important for succeeding in subjects such as English and maths.

Research overseas has shown that WM capacity is linked to, and can be predictive of: performance on English and maths ability tests (Alloway & Alloway, 2010) as well as achievement on national school curriculum tests of English and maths (Gathercole & Pickering, 2000; Gathercole, Pickering, Knight et al., 2004; St Clair-Thompson & Gathercole, 2006). However no research has been undertaken in New Zealand to explore whether WM performance is linked to tests and assessments used within the national school curriculum to assess progress in these subject areas. The present study aims to establish if this link is apparent.

Prevalence estimates of children with WM problems are difficult to find as there has been very little research on low WM as a primary topic. Alloway, Gathercole, Kirkwood et al. (2009a) found approximately 11% of children in their sample had WM impairments, and 63 to 71% of these children failed to meet age standardised scores on tests of English and maths. These statistics were obtained from a British sample, and low WM was classified on the basis of one verbal WM task, listening recall, and one visuo-spatial WM task, spatial recall. Inclusion criteria was a standard score of (≤ 81). The current study aims to gather prevalence statistics for low WM, inclusive of impairments in verbal and/or visuo-spatial STM, among New Zealand children and examine its possible relationship to English and maths.

The previous chapters have highlighted that children with low WM exhibit certain behaviours in the classroom that have been related to the demand of classroom activities (Alloway, Gathercole, Holmes et al., 2009; Alloway, Gathercole, Kirkwood et al., 2009b; Gathercole, Alloway, Kirkwood et al., 2008; Gathercole, Lamont et al., 2006). A search of the databases did not reveal any research relating to ratings of WM behaviour in New Zealand classrooms. This study aims to gather ratings from classroom teachers using a tool that is designed specifically to identify problem behaviours associated with low WM and to ascertain if there is a relationship between WM scores and ratings.

Previous research has identified behaviours of children with low WM in the home setting by using ratings scales, filled in by parents. These questionnaires are broad based and designed to capture deficits in a broad range of executive functions as well as symptoms of ADHD (Alloway, Gathercole, Holmes et al., 2009; Gathercole, Alloway, Kirkwood et al., 2008). A search of the databases did not identify any research in New Zealand where children with low WM have been rated using dedicated WM rating scales. This study aims to gather parent ratings of low WM behaviour in the home and explore what the relationship is to WM scores.

The previous chapters highlighted that there are many variables that can have an impact on WM in children, such as acquiring a TBI, being born very preterm, having:

ADHD, a learning disorder, mood problems, or being exposed to family violence. The present study will attempt to ascertain whether children with low WM scores are more likely to have these difficulties.

In summary, the aims and hypotheses of the present study are to:

1: Ascertain prevalence rates of low WM in a group of primary school children aged 9 to 11 years (Years 5 and 6).

Hypothesis 1:

Eleven percent of the sample may have deficits in WM.

This hypothesis is loosely based on research by Alloway, Gathercole, Kirkwood et al. (2009a) just previously mentioned. It is difficult to ascertain from the report on their study as to whether scores from both screening tasks had to be impaired to qualify as WM impairment. The present study will use both verbal and visuo-spatial STM and WM tasks as a marker to ascertain WM impairment with a different score criterion. Accordingly the results may yield a different percentage of WM impairment than specified.

2: Explore the developmental growth of WM in children aged 9 to 11 years.

Hypothesis 2:

There will be an increase in WM scores across age groups equated with age related growth.

This hypothesis is based on Alloway et al.'s (2006) finding that there is age related growth across verbal and visuo-spatial STM and verbal and visuo-spatial WM from ages 4 to 11 years.

3: Explore the relationship between academic performance in reading and maths in the New Zealand school curriculum and WM in a group of year 5 and 6 primary school children.

Hypothesis 3:

Children who are failing to achieve in reading and maths in school assessments will perform lower on WM measures than children that are achieving at average levels.

This hypothesis is based on studies that have found that children who have performed poorly on WM assessments also fail to perform at expected levels in national curriculum assessments of reading and maths in Britain (Gathercole & Pickering, 2000; Gathercole, Pickering, Knight et al., 2004; Jarvis & Gathercole, 2003; St Clair-Thompson & Gathercole, 2006).

4: Explore the relationship of WM scores to teacher's ratings of classroom behaviour and parent's ratings of behaviour at home.

Hypothesis 4a:

Children with lower WM scores will be rated by their teachers as having more frequent behaviours relating to WM problems, than children with average or above WM scores.

This hypothesis is based on research using the Working Memory Rating Scale (WMRS, Alloway, Gathercole, & Kirkwood, 2008) to measure the difficulties associated with low WM in children. Alloway, Gathercole, Kirkwood et al. (2009b) found that children with low WM scores obtained higher ratings of problem behaviours than children with average WM scores. Similarly, Gathercole, Kirkwood, et al. (2008) found that children with lower WM scores obtained higher teacher ratings in items on the BRIEF and CTRS measuring initiation, WM, planning/organisation, and emotional control.

Hypothesis 4b:

Children with lower WM scores will be rated by their parents/caregivers as having more frequent behaviours relating to WM problems, than children with WM scores that are average or above.

This hypothesis is based on research findings that parents rate children with lower WM scores as inattentive (Lui & Tannock, 2007). It is also based on research with children that have other conditions, (i.e., ADHD and/or TBI, which have been linked to WM deficits). Parents of children with these conditions have been found to rate their children as having impaired executive functions (Conklin et al., 2008; Joyner et al., 2009).

5: Ascertain if any children in the study have any known difficulties in the areas of ADHD, learning disorders, premature birth, TBI, mood problems, or trauma exposure. Explore if any of these variables have a correlation with WM scores.

Hypothesis 5:

Children with low WM scores will be more likely to be reported by their parents/caregivers as having had experienced one or more of the following; a brain injury, learning disorder, mood disorder, ADHD, born < 32 weeks, experienced trauma.

This hypothesis is based on research that has found lower WM and attention scores for children assessed as being anxious (Günther et al., 2004; Aronen et al., 2005), depressed (Brookes et al., 2010), experienced trauma (DePrince et al., 2009), ADHD (Martinussen & Tannock, 2006), learning disorders (Gathercole, Alloway, et al., 2006; Geary et al., 2009; McLean & Hitch, 1999, Siegel & Ryan, 1989), specific language disorder (Hutchinson et el., 2012), TBI (Moran & Gillon, 2004; Gorman et al., 2011), Very pre-term births (Luciana et al., 2004; Rose & Feldman, 1996).

Chapter 6
Method

Special Considerations/Deliberations for Data Collection

Administration. The study was originally comprised of two parts, a screening of all students, and a more in depth examination of two student groups. It was planned that part one would involve screening all year 5 and 6 students for WM ability, possibly using a group format. Obviously in a group screening situation, answers would have to be written. However, a small pilot study revealed difficulties with this as students took short cuts. For example, when asked to remember and write down a sequence of numbers in backward order, the child could store the numbers mentally and then when told to write them down could reproduce them on paper by writing down the first number called at the right-hand end of the answer sheet and work backwards, without having to mentally process the numbers into a backward sequence at all.

Furthermore, the pilot study revealed that the screening and explanation process would take approximately 45 – 50 minutes without factoring in practice trials for some of the measures. Most period blocks at the school last approximately 45 minutes. It was obvious then that for screening purposes written responses for that amount of time was untenable. Individual screening of children on the other hand would entail a considerable amount of time for the researcher and would also cause much disruption to classes by having children coming and going for individual testing for possibly two lengthy periods of time: WM screening, and full battery testing. It was then decided that to avoid these problems a different method to acquiring groups for the first part of the study would be needed.

Grouping children. Previous research has found that WM is predictive of achievement on nationally standardised tests of numeracy and literacy (Gathercole & Pickering, 2000; Gathercole, Pickering, Knight et al., 2004; St Clair-Thompson & Gathercole, 2006). The most efficient way to initially capture participant groups then, was to obtain two groups of children, one group who were performing at an average level, and the other performing below or well below the average level in tests and assessments of literacy and numeracy in the New Zealand school curriculum. This data is already collected by the school through routine, regular, and compulsory assessment. Since schools differ slightly in the measures that they use, it was decided to undertake the study at only one school to ensure numeracy and literacy achievement was measured using the same tests and assessments.

Ethical Issues

This study was designed and implemented in accordance with The Code of Ethical Conduct for Research, Teaching and Evaluations Involving Human Participants, Massey University (2010) and approved by the Massey University Human Ethics Committee. Issues that required special consideration were the risk of harm to participants, and confidentiality. To ensure that participants: children, parents, and teachers were explicitly aware of their rights and fully informed about the nature, logistics, and implementation of the study, information sheets and consent forms were prepared and provided to all (see Appendices I – VI). Children and teachers were reminded of their rights when the study was presented at the year 5 and 6 assembly and again before WM testing was commenced with the children/when the questionnaires were distributed to teachers.

The information sheets clearly explained the purpose of the study and how it would be conducted, in a manner and language that was appropriate for the target groups (children, teachers, and parents). This was to enable potential participants to be able to make a fully informed decision on whether or not they wished to participate. Parents were asked in their information sheet to talk with their child about the information provided on the study before giving permission for their children to participate (if consented to). They were also encouraged to contact the researcher if they had any questions or concerns about the study. Parents were asked to sign, date, and return the permission/consent form to allow their child's and their own participation in the study, this indicated that they understood their rights as research participants.

Confidentiality of assessment and questionnaire information was emphasised in all forums. None of the information gathered from measures used with the students, teachers, or parents was shared with any other participant. Likewise it was emphasised that the information gathered would not be shared with the principal/school. It was also stressed that participation in the study was voluntary and children could further withdraw even if their parents had previously given permission for them to participate.

Research Setting

All year 5 and 6 students (N=197) from a primary school in the Papamoa suburb of Tauranga were invited to take part in this study. The school is co-educational and consists of classes that begin from new entrant through to year six, comprising an age range from 5 – 11 years. Children in years 5 and 6 are grouped together in a senior syndicate and range in age from 8 - 11 years. They are taught together in seven composite classrooms, with one teacher in each class. This primary school has a current decile rating of five (Education Review Office, 2012). This rating denotes that families of children that attend this school fall within the mid-range of socio-economic factors. These factors are drawn from the NZ Census which are recalculated every five years. Papamoa (Population, 20,100) is the largest suburb in Tauranga and is situated along a coastal strip in the Bay of Plenty, which is on the east coast of the North Island of New Zealand.

Measures

Educational measures. The numeracy and literacy assessments that were used to separate the participant students into average and below average academic groups had been carried out as part of routine assessment by the school during the last week of August and the first week of September 2012. The literacy skills of interest for the purposes of this study were reading skills relevant to years 5 and 6 children. Similarly general maths skills were of interest. The tests and assessments utilised by the school to assess achievement in National Standards for the NZ school curriculum in reading and maths for children in years 5 and 6 for this time point were:

1. "E" asTTle – Reading comprehension and related skills
2. Reading Observations – Fluency, comprehension, accuracy
3. GloSS Testing – Maths, assesses global stages for operational strategies
4. PAT – Maths, number knowledge and strategies, algebra, geometry and measurement, statistics.
5. Basic Facts - Maths
6. Overall Teacher Judgements (OTJs)

All of the test and assessments listed above except for reading observations and OTJ's are standardised. Overall teacher judgement is derived from sources such as; observations of processes a student is using during learning situations; talking with the student to identify what they know, can do, and understand; gathering information from formal assessments (Te Kete Ipurangi, n.d.). OTJ's are useful if there are inconsistencies in assessment due to: test conditions, student motivation, engagement, preparation, and the nature and purpose of the assessment (Te Kete Ipurangi, n.d.). The information from the standardised scores from tests and assessments, the reading observations, and OTJ's are entered into a computer programme known as MUSAC - Classic ClassRoom Manager (MUSAC, 2012) which was designed to track and analyse assessment data. MUSAC then generates the level at which the child is currently achieving and whether this level is meeting the National Standard. A child's achievement can be described according to a four point scale: above, at, below, or well below National Standards (Te Kete Ipurangi, n.d.).

- **Above**: The student is currently performing above their year group, in a curriculum area.
- **At**: The student is currently at or meeting the standard in a curriculum area.
- **Below:** The student is not currently meeting the standard and is more likely achieving at a level of the previous year's standard in a curriculum area.
- **Well Below:** The student is not currently meeting the standard and is more likely achieving at a level more than one year below their current year.

Working memory measures. A brief selection of measures specifically dedicated to assessing WM and associated behaviour difficulties were used.

1. Automated Working Memory Assessment – Long Form (AWMA-L, Alloway, 2007).

The AWMA was developed by (Alloway, 2007) and is a fully computerised assessment tool. The computer programme contains three versions: the AWMA Screener, the AWMA Short Form (AWMA-S), and the AWMA Long Form (AWMA-L). Both teachers and other professionals can use the AWMA to screen people aged from 4 to 22 years of age for WM problems. The AWMA-L assesses three components of Baddeley and Hitch's (1974) WM model: the phonological loop, the visuo-spatial sketchpad, and the central executive using a variety of stimuli. It is made up of a battery of 12 tests. Three each of the tests assess verbal STM, verbal WM, visuo-spatial STM, and visuo-spatial WM. A composite score is given for each cluster of WM components.

The three verbal STM subtests are: digit recall, word recall, and non-word recall. The participant has to immediately recall sequences of information given audibly that gets progressively longer if responses on each trial are correct. The three verbal WM subtests are: listening recall, counting recall, and backward digit recall. In listening recall the participant has to listen to a series of sentences, judge and state if the sentence was true or false, and then repeat the last word of each sentence in the sequence they were presented.

The three visuo-spatial STM tests are: dot matrix, mazes memory, and block recall. In mazes memory a simple maze is presented on the computer screen with a red path leading from the centre of the maze outwards for 3 to 4 seconds. The participant then has to draw with their finger the same path on a subsequently presented blank maze. The mazes get progressively bigger and elaborate if the child continues to correctly draw each path.

The visuo-spatial WM tests are: odd one out, Mister X, and spatial recall. In the odd one out task a grid of three boxes are presented with a shape in each one, the participant must identify which one of the three shapes is not the same as the other two by pointing to it. The shapes then disappear from the grid and the participant must then recall which box the odd shape was in by again pointing to it on the screen. The 3 x 1 grids increase in number as correct responses are made. Standard scores are generated by the AWMA-L for each subtest and a composite standard score is given for each component of WM, based on the participants age (M = 100, SD = 15). Composite scores give a more informed assessment of WM performance. One standard deviation below the mean in a composite score denotes deficit in WM in a specific component, two standard deviations denote marked impairment.

A total of 1,269 individuals ranging in age from 4 to 22 years were tested in the standardisation sample. They came from a range of diverse ethnic backgrounds (European, African, Chinese, and Pakistani) and contained a proportionally equal number of males and females. Of this total 746 were children recruited from 22 primary schools in Britain. The participating schools represented a range from low, average, and high performing children in school assessments of English, mathematics, and science (Alloway, 2007).

The within construct components coefficients are moderate to highly correlated (range .59 - .97, generally clustering from .75 - .81) indicating good internal validity. The AMWA shows good concurrent validity with the *Working Memory Index* (WMI) of the Wechsler Intelligence Scale for Children Fourth UK Edition (Wisc-IV^{UK}, Wechsler, 2004; as cited in Alloway, Gathercole, Kirkwood, & Elliot, 2008).

The AWMA requires the use of a quiet room where the participant and tester can sit side by side at a desk in front of a computer. This is so that the participant can see the computer and hear the automated instructions and the tester can see, hear, and key in the participant’s responses. The assessment takes between 45 and 60 minutes to complete.

The testing sequence is automated with the STM verbal and visuo-spatial memory subtests being interspersed with the WM verbal and visuo-spatial subtests. Each subtest begins with some practice trials to familiarise the participant with instructions on how to complete the test. These can be repeated if the participant needs more practice. The test trials of the subtests then commence. The test trials are in blocks each block containing six trials. If four trials are completed correctly within a block the programme will proceed to the next block. If three or more mistakes are made within a trial the test stops and returns to the main screen where the scores for each subtest is shown.

2. Automated Working Memory Assessment – Screener (AWMA Screener, Alloway, 2007).

The AWMA Screener is a brief instrument for use by teachers or other professionals if WM problems are suspected. It consists of two subtests from the AWMA-L. If an individual's standard score for either subtest fall below 85 (<1 SD below the mean) a full assessment using the AWMA-L is recommended to investigate if other subtests measuring WM produce similarly low scores or normal scores. Going on to complete the AWMA-L will show where weaknesses in WM may lay, (i.e., which component(s)), and also locate the child's WM strengths (Alloway, 2007). The two subtests are one each of verbal WM: listening recall, and visuo-spatial WM: spatial recall. Practice trials for each of these subtests are also available before test trials are commenced. This test takes approximately 10 to 20 minutes to administer inclusive of practice trials.

3. Working Memory Rating Scale (WMRS, Alloway, Gathercole, & Kirkwood, 2008).

The WMRS is an easy to use behaviour rating scale for teachers to help identify children that may be at risk of low WM and subsequently achieving poor academic progress. The teacher must have had experience with the child on a regular basis for at least one month to provide accurate answers (Alloway, Gathercole, & Kirkwood, 2008). The WMRS is a single scale consisting of 20 questions specifically relating to classroom behaviours that are typically observed in children with low WM. Examples include: He/she looses track of where they are up to in an activity with many steps, he/she needs repeat reminders in written activities. These behaviours can assist in distinguishing children with low WM from children with average WM. The rater must choose ratings from 0 - not typical at all to 3 - very typical (Alloway, Gathercole, & Kirkwood, 2008).

The WMRS has been found to have good internal reliability illustrating that the questions are measuring a single factor. The scale also correlates with the more direct measures of WM, such as the AWMA subtests: listening recall (r = - .57), backward digit recall (r = - .59), and the WMI of the Wechsler Intelligence Scale for Children Fourth UK Edition (Wisc-IV^{UK}, Wechsler, 2004; as cited in Alloway, Gathercole, & Kirkwood, Elliot, 2009b), (r = - .51, *p* < .001). Higher T scores on the WMRS were significantly related to lower scores on these subtests. Sixty seven percent of the children assessed as having low WM via the AWMA and WMI of the WISC-IV, had elevated WMRS scores that identified WM deficits, whereas only 11% of the average WM group obtained the same elevated WMRS scores (Alloway, Gathercole, Kirkwood, & Elliot, 2009b). Raw scores for this scale are converted to T scores (*M* = 50, *SD* = 10). T scores of 60 - 70 signify moderate WM difficulties, T scores 70 and above denote pronounced WM deficits. See Appendix VII for a copy of the WMRS.

4. Working Memory Rating Scale for Parents and Caregivers (WMRS-PC). There is no formal WM scale for parents and caregivers. Rather the WMRS-PC is a questionnaire with 14 questions thought to relate to WM behaviours that may be observable in the home life of a child by their parent or caregiver. It was adapted by the author from the WMRS.

The WMRS-PC does not have the equivalent amount of questions as the WMRS, this is because some of the questions on the WMRS directly related to classroom behaviour and could not be readily converted into situations in the home. The questions on the WMRS-PC are broadly based on the questions asked in the WMRS, mainly relating to behaviours when carrying out homework tasks or any task with multiple steps in it. Examples include: When asked to do a task with multiple steps will abandon the task, requires regular repetition of instructions. The rating scale used is the same as the one used in the WMRS: 0 - 3, not typical at all – very typical. The WMRS-PC has not been standardised, but it is assumed that a higher raw score will identify children at risk of WM problems. In addition to questions relating to behaviours, five questions ask about possible influences on WM (e.g., has the child had a head injury/ been diagnosed with a learning disorder/mood disorder/ADHD/born < 32 weeks/experienced or witnessed trauma). See Appendix VIII for a copy of this rating scale and additional questions.

Procedure

Initial contact was made with the principal of the school, and details of the proposed study were discussed at length in a subsequent meeting. Approval was then given for the study to be undertaken at the school. After ethics approval for the study was given, students were recruited. At a senior school assembly all year 5 and 6 students and their teachers were addressed and informed about the study and invited to participate. The aim was to maximise student participation and hand out forms to every year 5 and 6 student in attendance. One hundred and sixty three information sheets and consent forms for both students and their parents were given out on the day of the assembly. Forms were also given to teachers to hand out to children who were not present on the day. Of these, 55 students returned permission forms. It was then decided to attend another senior school assembly a week later to remind children about the study and explain that more students were needed. Forms were made available for children who had lost/misplaced/did not have forms. Twelve more were taken by students and six of these were returned. In total 61 students returned consent forms. Four weeks after consent forms were returned, assessments commenced and were conducted over the following four week period.

Reading and maths achievement standards were examined for the 61 children for whom parental consent had been received. A variety of differing levels of achievement were observed. There were only 12 children in both years 5 and 6 that had consented to the study that fell well below the national standard for reading and/or maths. These children were selected for the study into the *below average* *academic group*. Twelve more children were selected based on achieving at the national standard in reading and maths for their year, these 12 students comprised the a*verage* a*cademic group*. The 24 children completed the AWMA-L.

The remaining 36 students (one student was absent for the duration of the data collection period and excluded) were assessed using the AWMA Screener. This revealed five students who were assessed as being at risk of having WM difficulties (scored at least 1 standard deviation below the mean in either of the subtests). These five students then went on with the previously chosen 24 students to complete the AWMA-L. The academic attainment of these five children revealed that four were performing below and one performing at the National Standard for reading and/or maths. Accordingly these five children were placed into the below average, and average academic groups respectively. Twenty nine children in total completed the AWMA-L: 16 below average, 13 average academically.

All 29 children who completed the AWMA-L took the WMRS-PC home for their parents to fill in and return. Their six teachers were given the WMRS to complete and return also. Questionnaire rating scales were completed and returned by parents and teachers of all 29 students.

The reviewed research has demonstrated that verbal and visuo-spatial STM and WM components have been implicated to differing degrees as being related to certain disorders and conditions and academic attainment. Therefore the participants who completed the AWMA-L were classified as having low WM if any of the four composite scores on the AWMA-L were (< 85, $N = 12$), average WM was assessed as all composite scores between (≥ 85 - ≤ 115, $N = 7$), and above average WM was categorised as any composite scores above (≥ 116, $N = 10$). These cut-offs were chosen as one standard deviation below the mean denotes impairment in a particular component of WM. One standard deviation above the mean denotes above average WM functioning (Alloway, 2007).

A flow diagram of the procedures for participant recruitment and measure utilisation is shown in Figure 6.1.

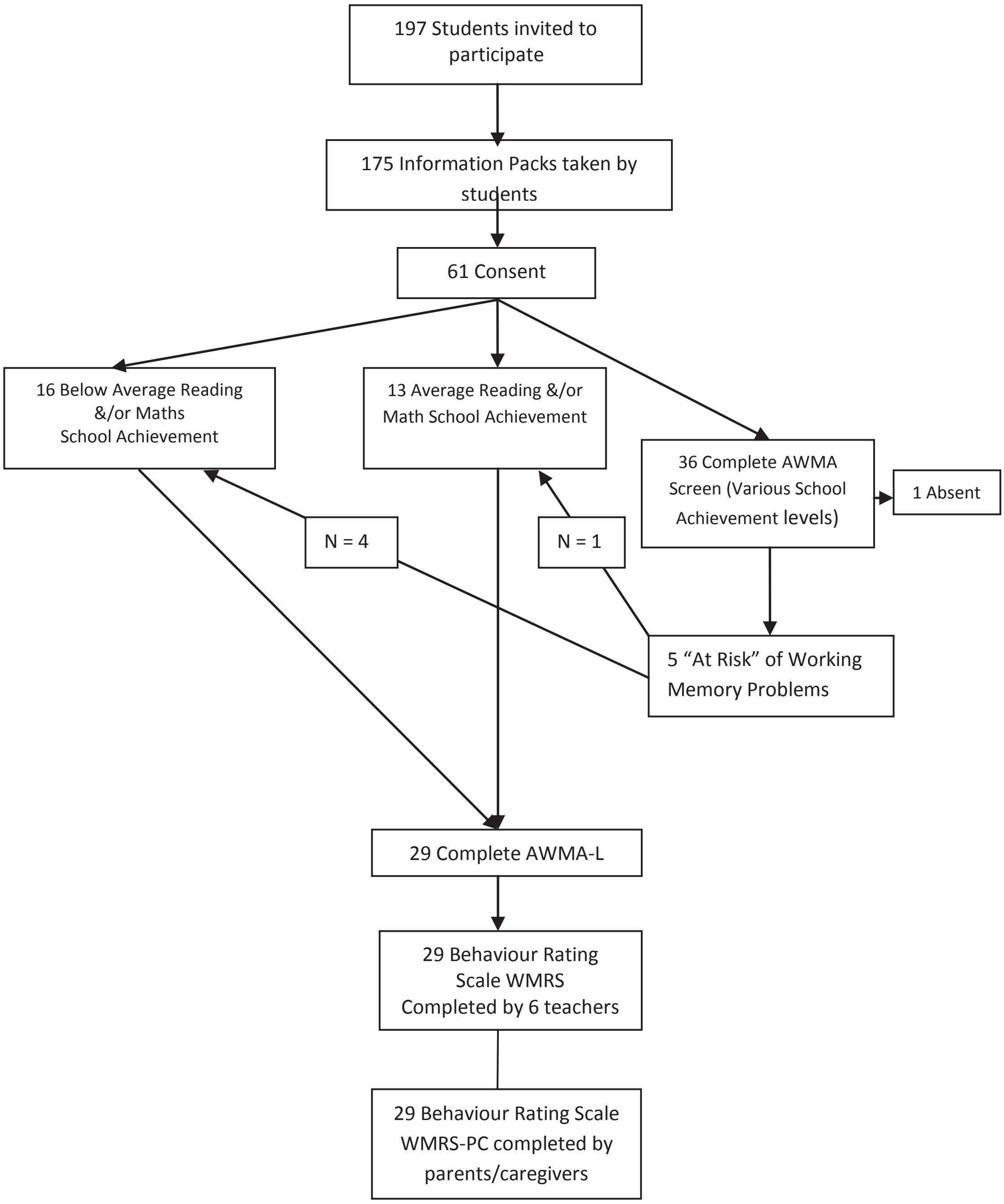

Figure 6.1

Flow diagram for procedure of participant recruitment

Participants

Demographics for the sample and how it was differentiated are presented in Table 6.1. The first column of numbers represents the total sample that either completed the AWMA Screener, or the same subtests involved extracted from the AWMA-L. The second column of numbers represents the academic groups; below average and average, who were chosen to complete all measures in the study.

Table 6.1

Demographic Characteristics of all Participants Who Completed the AWMA Screener and AWMA-L (N=60), and Demographic Characteristics of Participants Who Went on to also Complete the WMRS and WMRS-PC (N=29)

Characteristics		N (%)	N (%)
Gender			
	Female	33 (55)	12 (41)
	Male	27 (45)	17 (59)
	Total	60 (100)	29 (100)
Ethnicity			
	Maori	15 (25)	6 (21)
	NZ European	38 (63)	21 (72)
	Other European	5 (9)	2 (7)
	Pacific Islander	2 (3)	0
Age			
	9	10 (17)	4 (14)
	10	26 (43)	12 (41)
	11	24 (40)	13 (45)
Year			
	5	29 (48)	12 (41)
	6	31(52)	17 (59)

Chapter 7

Results

Hypothesis 1:

Eleven percent of the sample may have deficits in WM.

Using the same criteria of Alloway, Gathercole, Kirkwood et al. (2009), see Chapter 5, four (7%) of the original sample (N = 60) would be classified as having deficits in WM if only one or other subtest (listening recall or spatial recall) fell below the standard score of 81. If WM impairment was determined by both standard scores falling below 81 in both subtests then none of the sample in the current study would be classified as having WM deficit as no one child scored less than 81 in both subtests.

Using the criteria for the current study, 12 (20%) of the original sample (N = 60) were assessed as having deficits in one or more WM components as assessed by the AWMA-L. This result is based on 31 participants who had completed the AWMA Screener and the same two sub-tests used in the screener from the 29 who received the full AWMA-L.

All data for all groups was checked for skewness and kurtosis before statistical analysis was run. None of the skewness or kurtosis statistics were greater than twice the value of its standard error.

Hypothesis 2

There will be an increase in WM scores across age groups equated with age related growth.

All one way ANOVA calculations in the present study report Cohen's d, using ETA squared. There was a significant difference observed in the mean standard scores between the age groups for the listening recall subtest, $F(2, 57) = 4.02$, $p = .02$; η^2 = .12. The effect size for this analysis is considered medium. A post hoc analysis using Tukey's HSD revealed a significant difference between the mean standard scores of the

10 and 11 year old age groups (*p* = .02). However the difference in mean standard scores between the 11 and 9 year olds, and the 9 and 10 years olds did not reach significance, demonstrating that the 11 year olds performed lower on this subtest than the 10 year olds. No difference was observed in the mean standard scores between any of the age groups for the spatial recall subtest.

Table 7.1 presents the means and standard deviations of the standard scores for participants by age group who completed the AWMA Screener (*N* = 60).

Table 7.1

Means and Standard Deviations of Standard Scores Obtained on the AWMA Screener Based on Age of Participants

Subtests of AWMA Screener	9 yrs (*N* = 10) Means (*SD*)	10 Yrs (*N* = 26) Means (*SD*)	11 Yrs (*N* = 24) Means (*SD*)	Total (*N* = 60) Means (*SD*)
Listening Recall	109.60 (16.00)	111.57 (15.72)	99.05 (16.58)	106.24 (16.93)
Spatial Recall	112.40 (11.29)	111.84 (16.33)	108.65 (18.59)	110.66 (16.43)

One way ANOVA was computed on the raw scores across the age groups for the listening recall and spatial recall subtests, and no significant differences were found.

Twenty-nine of the sample of 60 received the full AWMA-L and the means and standard deviations of the standard scores and composite scores are presented in Table 7.2 below. The norms reported for the AWMA-L are standardised scores (*M*= 100, *SD* = 15) per age band. The only significant difference observed in any of the mean standard scores between any of the age groups for any of the subtests was for the digit recall subtest, $F(2, 26) = 3.98$, $p = .03$; $\eta = .23$. The effect size for this analysis is considered large. A post hoc analysis using Tukey's HSD, however, revealed no significant differences between any of the groups. Although it appears from comparing the means across the age groups for this test, the 11 year olds received a lower standard score than the 9 and 10 year olds.

Table 7.2

Means and Standard Deviations for Subtests and Composite Standard Scores of the AMWMA-L Based on Age of Participants

Subtests of AWMA-L	9 yrs (*N* = 4) Mean (*SD*)	10 yrs (*N* = 12) Mean (*SD*)	11 yrs (*N* = 13) Mean (*SD*)	Total (*N* = 29) Mean (*SD*)
Verbal STM				
Digit Recall	105.75(17.09)	101.65 (12.81)	89.42 (11.50)	96.73 (14.12)
Word Recall	104.00 (10.42)	100.66 (11.97)	94.43 (14.30)	98.33 (13.02)
Nonword Recall	108.75 (14.36)	102.56 (16.93)	93.08 (13.88)	99.17 (15.91)
Composite VSTM	107.50 (14.24)	102.00 (15.38)	90.07 (14.95)	97.41 (16.10)
Verbal WM				
Listening Recall	104.75 (16.60)	111.00 (15.52)	94.81 (18.88)	102.89 (18.33)
Counting Recall	114.75 (1.50)	103.50 (13.76)	99.46 (19.32)	103.24 (16.13)
Backward Digit Recall	94.25 (11.61)	92.50 (10.06)	90.17 (13.08)	91.70 (11.40)
Composite VWM	106.25 (3.20)	103.00 (13.23)	93.84 (18.38)	99.34 (15.53)
VisuoSpatial STM				
Dot Matrix	104.75 (5.18)	97.74 (13.63)	103.44 (20.98)	101.26 (16.55)
Mazes Memory	107.50 (12.34)	103.33 (20.98)	103.67 (14.87)	102.82 (17.03)
Block Recall	104.00 (7.07)	97.83 (12.98)	92.76 (12.54)	96.41 (12.42)
CompositeVSSTM	107.00 (9.48)	98.08 (16.19)	99.30 (14.64)	99.86 (14.60)
VisuoSpatial WM				
Odd-One-Out	1112.25 (5.96)	110.25 (12.32)	104.38 (15.96)	107.90 (13.54)
Mister X	102.25 (17.72)	111.75 (12.43)	99.63 (14.72)	105.00 (14.87)
Spatial Recall	109.75 (13.07	101.16 (13.37)	107.11 (10.67)	105.01 (12.20)
Composite VM	109.00 (12.32)	109.83 (12.36)	103.53 (13.77)	106.89 (12.93)

Again a one way ANOVA was computed to investigate differences in raw scores across the age groups on all subtests of the AWMA-L and no significant differences were found.

Hypothesis 3:

Children who are failing to achieve in reading and maths in school assessments will perform lower on WM measures than children that are achieving at average levels.

Figure 7.1 below illustrates the number and percentages of students achieving below average or average and above WM scores according to academic achievement.

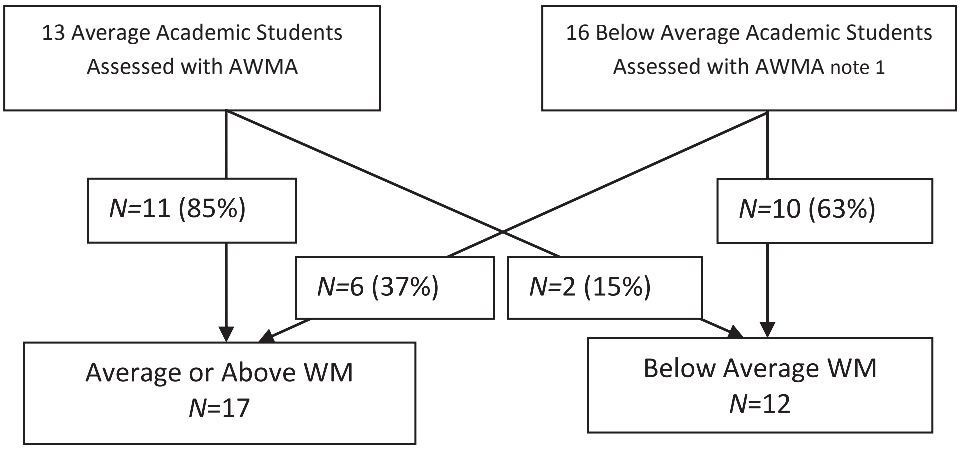

Figure 7.1. Categorisation of academic groups into WM groups based on standard scores achieved on the AWMA-L.

Note 1. Below Average Reading and Maths (*N* = 8); Below Average Maths only (*N* = 6); Below Average Reading only (*N* = 2)

For the purposes of all Chi-Square analysis the average and above WM memory groups were combined to increase expected cell counts. Where appropriate (if any expected cell counts were less than five) Fishers Exact Test p value will be reported, instead of the chi-square statistic. Cramer's V is the effect size statistic reported for all chi square calculations where appropriate. Chi-square 2 x 2 test of association demonstrates a significant difference between academic groups and their categorization into WM groups (low or average and above) based on participant's scores on the AWMA-L.

$\chi^2(1, N = 29) = 4.76$, $p = .029$, $\phi = .48$. The effect size for this finding is considered moderate.

It was thought to investigate the extent to which the lower mean WM standard scores for the below average academic group were attributable to the student's specific area of under achievement (English and/or maths). However as the group sizes were small, no statistical analyses were performed.

Significant differences were found between the below average and average academic groups in all subtests of the AWMA-L except for digit recall, with the below average academic group performing at significantly lower levels than the average academic group. The differences were more pronounced for all of the verbal WM subtests and two out of three each of the visuo-spatial STM and WM subtests. Differences as reported in Table 7.3 below.

Table 7.3

Comparison of Below Average and Average Academic Groups on subtests of the AWMA-L

	Below Average	Average	*t*	*P*
Verbal STM				
Digit Recall	93.64	100.54	-1.32	0.10
Word Recall	94.92	102.53	-1.68[a]	.05*
Nonword Recall	93.29	106.4	-2.38	.01**
Verbal WM				
Listening Recall	94.34	113.40	-3.21	<.001***
Counting Recall	95.74	112.48	-3.20	<.001***
Backward Digit Recall	87.33	97.08	-2.49	<.001***
Visuo-Spatial STM				
Dot Matrix	93.65	110.63	-3.15	<.001***
Mazes Memory	96.74	110.30	-2.29	0.01**
Block Recall	91.23	102.79	-2.77	<.001***
Visuo-Spatial WM				
Odd-One-Out	101.01	116.39	-3.64	<.001***
Mister X	99.54	111.74	-2.36	<.01**
Spatial Recall	97.77	111.47	-2.88	<.001***

*, **, *** Denotes a significant result at .05, .01, .001 respectively
[a] Levene's test of equality of means indicates that the means were not equal, therefore the unequal means t-value, degrees of freedom, and p-value were used.

Composite standard scores for all four components of WM across both academic groups are illustrated in Figure 7.2.

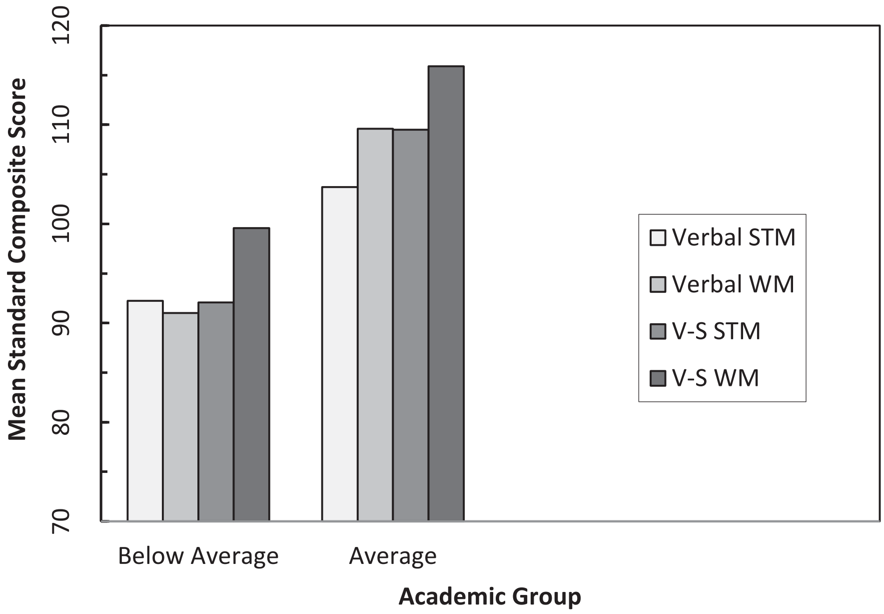

Figure 7.2. Mean performance of academic groups on the AWMA-L grouped by WM composite scores.

This figure shows that mean performance on all measures for the average academic group was above the standard score of 100, verbal STM (*M* = 103.8, *SD* = 15.04), verbal WM (*M* = 109.61, *SD* = 14), visuo-spatial STM (*M* = 109.46, *SD* = 11.14), visuo-spatial WM (*M* = 115.92, *SD* = 11.01). The below average academic group obtained similar composite means scores across: verbal STM (*M* = 92.25, *SD* = 15.47), verbal WM (*M* = 91.00, *SD* = 11.32), and visuo-spatial STM (*M = 92.06*, *SD* = 12.42), visuo-spatial WM (*M* = 99.56, *SD* = 9.34).

T tests were conducted on the composite mean scores across all four WM components assessed. Statistical significance was found between groups for all components; verbal STM, $t(27) = -2.02$, $p = .02$, $d = .76$, verbal WM, $t(27) = -3.96$, $p = < .001$, d = 1.24, visuo-spatial STM, $t(27) = -3.92$, $p = < .001$, d = 1.16, visuo-spatial WM, $t(27) = -4.33$, $p = < .001$, d = 1.09. Demonstrating that the average academic group's WM performance on the AWMA-L was superior to that of the below average academic group. All effect sizes exceed Cohen's convention for a large effect with the exception of the effect size for verbal STM, which is considered a medium effect. Of note is that the aggregate mean composite standard scores of the below average academic group did not fall below 85.

Hypothesis 4a:

Children with lower WM scores will be rated by their teachers as having more frequent behaviours relating to WM problems, than children with average or above WM scores.

One way ANOVA confirmed that there was a significant difference between the scores of the WM groups on the WM rating scale WMRS; low WM (M = 63.50, SD = 8.0), average WM (M = 52.43, SD = 13.95), and above average WM (M = 48.10, SD = 9.57). $F(2,26) = 6.59$, $p = .005$, $\eta^2 = .34$. The effect size for this finding is considered large. A post hoc analysis using Tukey's HSD confirmed that there was a significant difference in WMRS ratings between the above average and below average WM groups on the WMRS ratings, $p = .004$. However, there were no significant differences in means found on WMRS ratings between the average and above average and average and below average groupings.

One standard deviation above the mean T score of 50 on the WMRS denotes deficits in WM (Alloway, Gathercole, & Kirkwood, 2008). Therefore, scores on the teachers WMRS were split into two groups; T scores that were (≤ 60) were defined as a *typical classroom behaviour*, T scores that were (≥ 61) were defined as *atypical classroom behaviour* resulting in groupings shown in Table 7.4. Chi-square analysis revealed a significant difference between the low and combined average and above WM groups and their categorization into either the typical or atypical classroom behaviour grouping at p = .001, $\phi = .64$. This effect is considered large. The low working memory group was rated as displaying significantly more behaviours relating to working memory difficulties than the average and above group. This result shows that (75%) of the low WM group were rated as having WM difficulties by their teacher.

Table 7. 4

Comparison of WM Groups Based on Typical or Atypical T Scores on the WMRS as Rated by Teachers

	WM Grouping		
	Average & Above	Below Average	Total
WMRS Grouping			
Typical	15	3	**18**
Atypical	2	9	**11**
Total	**17**	**12**	**29**

As 63% percent of the below average academic group had membership in the low WM group it was again thought to compare academic groups on mean T scores of the WMRS. An independent samples t test confirmed that there was a significant difference between the scores of the academic groups as rated on the WMRS. Levene's test of equality of means indicated that the means were not equal, therefore the unequal means t-value, degrees of freedom, and p-value are reported; below average academic group (M = 63.56, SD = 9.91), average academic group (M = 45.62, SD = 4.94), $t(23) = 6.33,$ p = < . 001, ɗ = 1.79. The below average academic group were rated by their teachers to display more behaviours related to WM difficulties than the average academic group. The effect size for this statistic is considered large.

Chi-square analysis comparing academic groups with typical and atypical T scores rated on the WMRS confirmed that there was a significant difference between groups, with the below average academic group being categorized as having more scores in the atypical range than the average academic group, p = < .001, ϕ = .70. The effect size for this finding, is considered large. Sixty nine percent of the below average academic group were rated by their teachers as showing behaviours related to WM difficulties by their teachers.

Hypothesis 4b:

Children with lower WM scores will be rated by their parents/caregivers as having more frequent behaviours relating to WM problems, than children with WM scores that are average or above.

A one way ANOVA was conducted and found that there were also significant differences observed in the mean raw scores of the WMRS-PC between all three WM groups, with higher scores indicating more frequent behaviours related to WM difficulties. Low WM group (*M* = 23.92, *SD* = 8.46), average WM group (*M* = 11.43, *SD* = 9.34), and above average WM group (*M* = 13.40, *SD* = 8.93). $F(2,26) = 5.89$, $p = .008$. $\eta^2 = .31$, the effect size for this finding is considered large. Post hoc analysis using Tukey's HSD revealed that there were significant differences between the means of the low WM group and average WM group, $p = .017$, and also the low WM group and above average WM group, $p = .026$. Indicating that as memory scores decrease WM behaviours become more apparent to raters.

Again scores from the WMRS-PC were split, this time based on raw score performance resulting in allocation to groups shown in Table 7.5. This formulation was based on the mean raw score obtained across all participants (*M* = 17). If scores fell at (≤ 17) this was classed as typical behaviour, if scores were (≥ 18) this was classed as possible problem behaviour. A significant difference between WM groups and their classification by WMRS-PC grouping was found, χ^2 (1, *N* = 29) = 7.82, $p = .005$, $\phi = .59$. The effect size for this finding is considered large. Parents rated (83%) of children with low WM as having problem behaviours related to WM. Conversely parents rated only (23%) of children with average and above WM as having problem WM behaviour.

Table 7.5

Comparison of WM Groups Based on Scores Reflecting Typical or Problem Behaviours as Rated by Parents on the WMRS-PC

	WM Grouping		
	Average & Above	Below Average	Total
WMRS-PC Grouping			
Typical	13	2	**15**
Problem	4	10	**14**
Total	**17**	**12**	**29**

Again, as the below average academic group had 63% of their group assessed as having low working memory, statistical analysis was performed; comparing the academic groups mean raw scores obtained on the WMRS-PC, and classification of WM behaviour as designated by higher scores on the WMRS-PC. An independent samples t test found a significant differences between academic groups mean raw scores: below average academic group (*M* = 20.25, *SD* = 9.95), average academic group (*M* = 13.62, *SD* = 9.77), *t*(27) = 1.8, *p* = .04, d = .67, this effect size is considered medium. However chi square analysis revealed no significant differences in association between academic groups and scores on the WMRS-PC that would classify either group as being rated as having more problem behaviour or typical behaviour.
χ^2 (1, *N* = 29) = 1.76, *p* = .185.

Hypothesis 5:

Children with WM scores will be more likely to be reported by their parents/caregivers as having had experienced one or more of the following; a brain injury, learning disorder, mood disorder, ADHD, born < 32 weeks, experienced trauma.

Three parents/caregivers of students in the low WM group reported that their children had a language/or learning disorder, although did not specify which, and two parents reported that their children had a language disorder. In total, five (42%) parents of children in the low WM group reported disorders. Four parents/caregivers of children in the average WM group reported that their children had suffered a TBI or experienced/witnessed trauma (57%). Only one parent of a child in the above average WM group reported their child having experienced other possible influences on WM, namely TBI (10%). Figure 7.3 illustrates the incidence of the disorders reported. Missing bars in each WM group illustrate that no children were reported as having experienced these difficulties/disorders.

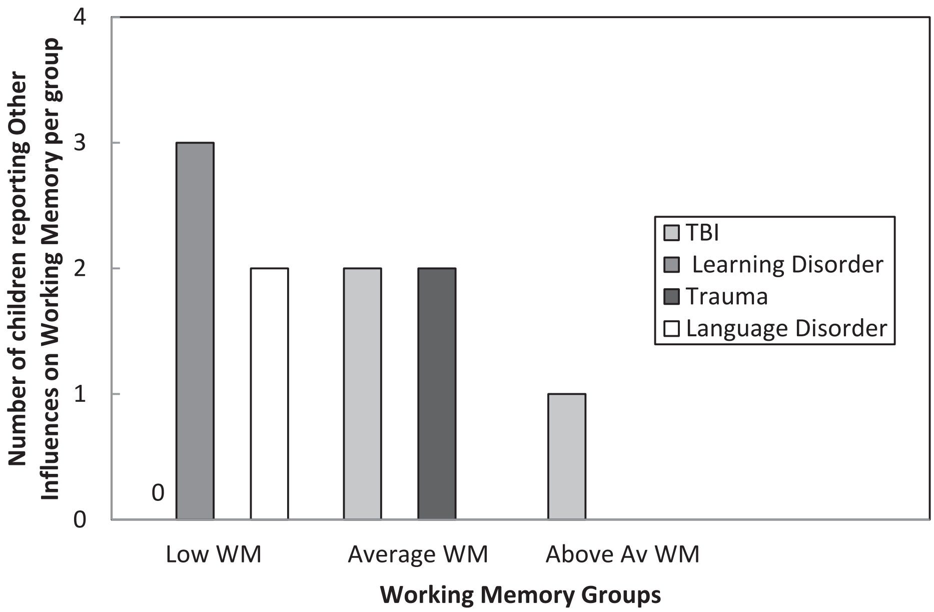

Figure 7.3. Incidence of other influences on WM reported by parents as categorised by WM group.

None of the other disorders mentioned in Hypothesis 5 were reported; mood disorders, ADHD, born < 32 weeks gestation.

Chi square analysis found no significant differences between the low WM group and the average and above WM group relating to disorders or experiences reported, $p = .69$.

Chapter 8

Discussion

The present study examined the prevalence of WM difficulty in children aged 9 - 11 years in a New Zealand school and the association between WM and achievement in reading and maths. It also examined the growth of WM across these age groups. Additionally, WM and its association with: behaviour at school, at home, and other influences were examined. Participant students completed a WM assessment and their scores were compared to reading and maths attainment, and teacher and parent behaviour ratings.

It was hypothesised that 11% of the participants would have difficulties with WM, and that there would be age related growth in WM scores across the sample. It was further hypothesised that if academic achievement was low, WM scores would also be low. It was also hypothesised that teachers and parents would rate children with low WM as displaying more frequent behaviours relating to low WM. A further hypothesis was that children who score low on WM tests would be more likely to have experienced either a: TBI or some type of trauma; or had a diagnosis of: learning disorder, language disorder, ADHD, or mood disorder.

The results supported some hypotheses and not others. Low WM scores were found to be related to below average performance in reading and maths at school; and higher teacher and parent ratings of low WM behaviour was related to low WM scores. However the hypothesis that there would be age related growth in WM was not supported. Neither was the hypothesis that children with low WM would be more likely to: have an existing diagnosed disorder, or have experienced other influences on WM.

Prevalence of WM Problems

The percentage of participants who were assessed as having WM deficits in one or more components of WM was (20%, *N* = 12) in the present study. This percentage is higher than that found by Alloway, Gathercole, Kirkwood, and Elliot (2009a). The result may be higher in the present study for three reasons. Firstly, the cut-off score to demarcate WM impairment in Alloway, Gathercole, Kirkwood, and Elliot's (2009a) study was lower than that utilized in the present study. Secondly, the present study categorised children into the low WM group based on achieving cut-off scores in STM and/or WM components, not just WM. Thirdly, it is possible that more parents with children who were achieving at lower levels academically, consented to the study, and WM impairment has been found to be related to academic underachievement (Alloway, Gathercole, Kirkwood, & Elliot, 2009a; Gathercole & Pickering, 2000).

Age Related Growth in WM Scores

An increase in WM scores across the age groups from 9 – 11 years was not found in the current study. In fact the opposite was found, with a decreasing trend for 8 of the 12 subtests, inclusive of all of the verbal STM and WM subtests, as ages increased. However, this decrease only reached significance for the verbal WM subtest; listening recall, in the screening phase, and the verbal STM subtest; digit recall, completed in the full assessment. It is unclear why this lack of difference and decrease (significant and non-significant) was apparent in scores among the larger screened sample of 60, according to age. In their study on WM development Alloway et al. (2006) found that scores for verbal STM levelled out for the 11 and 12 year old age group. Although their finding does not explain the decrease here, it may assists in explaining why there may have been no significant increase in verbal STM scores.

The full assessment using the AWMA-L was completed by 29 participants and the finding of no difference and decreasing scores (significant and non-significant) found at that stage, may have been due to the fact that the majority of children in the low WM group were in the 11 year old age bracket: (9 years: N = 0, 10 years: N = 4, 11 years: N = 8). Similarly, all of the 9 year olds in the study group of 29 and nine of the 10 year olds were in the average or above WM groups. Therefore absence of a finding for age related growth could be the result of sample recruitment and the way that the 29 children were selected.

WM and Academic achievement

Group classification. Eighty three percent (*N* = 10) of the low WM group in the present study were in the below average academic group. This percentage is slightly higher than for a younger group reported by Alloway, Gathercole, Kirkwood, and Elliot (2009a) where 68 – 71% of 8 to 9 year olds with WM difficulties struggled to achieve average reading and maths. Findings of differing percentages of low academic achievement in low WM groups could be due to academic group classification. Alloway, Gathercole, Kirkwood, and Elliot (2009a) relied on the Wechsler Objective Reading Dimensions (WORD; Wechsler, 1993; as cited in Alloway, Gathercole, Kirkwood, & Elliot, 2009a), and the Wechsler Objective Numerical Dimensions (WOND; Wechsler, 1996; as cited in Alloway, Gathercole, Kirkwood, & Elliot, 2009a) to obtain their academic results. In a similar study, Gathercole and Pickering (2000) undertook a fine grain analysis of tests and assessments used by the schools involved in their research and selected their academic groups based on inclusion criteria that relied on specific cut-off points in only standardised tests and assessments with no teacher judgements included.

Perhaps the stringent academic inclusion criteria used in these two studies identified a smaller group of children that were achieving poorly academically. The below average academic inclusion criteria used in the present study was based on standardised tests, teacher judgements, and included children achieving across two levels below National Standards (below and well below) in reading and maths, for their year in the NZ school curriculum. Therefore the present study possibly included more children that were under achieving in English and maths, that had potential for WM difficulties.

The finding that performance at lower than average levels of achievement in tests and assessments of reading and/or maths in the New Zealand school curriculum is linked with poorer WM performance is consistent with previous research demonstrating the association between WM and academic achievement (Alloway & Alloway,2010; Alloway, Gathercole, Kirkwood, & Elliot, 2009a; Alloway & Passolunghi, 2011; Bull, Espy & Wiebe, 2008; Gathercole & Pickering, 2000; Gathercole, Pickering, Knight el al., 2004). The aforementioned research spans age groups from four to fifteen years.

If classification of groups are reversed (10 assessed as having low WM, from the total below average academic group of 16) the below average academic group had only (63%) of their group classified as having low WM. The same argument used above regarding academic sampling could be used also; in the present study the upper limit of academic inclusion could also translate to including children with less impaired academic achievement and similarly typical WM. As Gathercole, Pickering, Knight et al. (2004) point out, the relationship between crystallized knowledge and WM ability, though strong is not perfect. A more useful explanation emerged after results were analysed; academic achievement may be influenced by many variables such as family income, parental education level and occupation (Engle, Santos, & Gathercole, 2008). Therefore although academic achievement maybe low, it may be the result of other environmental experiences rather than WM which has been found to be impervious to SES (Engle et al., 2008).

WM subtests. All subtests in the AWMA-L battery with the exception of digit recall sufficiently discriminated between the below average and average academic groups, with the below average group performing significantly lower across all four domains of verbal and visuo-spatial STM and WM than the average group. This finding corroborates previous research that WM improves across academic groups from low to higher performers (Gathercole, Pickering, Knight et al., 2004).

The digit recall subtest did not discriminate significantly between the two groups, but there was a trend, in that, the below average academic group's score on this subtest was lower. Possibly significance was not met because the subtest was not too taxing on WM as it is a verbal storage task only. However the two other verbal storage tasks significantly discriminated between the groups but not to the extent of the verbal and visuo-spatial WM, and the visuo-spatial STM tasks, supporting Alloway, Gathercole, Kirkwood, and Elliot's (2009a) finding of more deficit in these components in low WM groups.

The standard scores for the verbal WM subtests were the most discrepant between the below average and average academic groups in the present study. Backward digit recall (Gathercole and Pickering, 2000), and listening recall (Gathercole, Pickering, Knight et al., 2004) have been found to be good predictors of membership into low academic groups. Both these studies also found nonword recall, a verbal STM measure to be as equally predictive. Though nonword recall significantly discriminated between the two academic groups in the present study, it was not as significant a difference as the WM subtest scores.

The present study did not investigate the relationship between WM scores and specific areas of low academic achievement, (i.e., English, or maths, or a combination of both), due to small numbers in these sub groups. Most of the children in the below average academic group were under achieving in maths, 88%: Half of the below average academic group were not achieving in both subjects, and six more were not achieving in maths only. Visuo-spatial STM and WM, and verbal WM have been found to be important for maths achievement (Alloway & Passolunghi, 2011; Zheng et al., 2011), and has been found to be deficient in children with maths disorders (Geary et al., 2009; McLean & Hitch, 1999; Swanson & Beebe-Frankenberger, 2004). Therefore low maths performance may help to explain the significant difference between the academic groups on these measures and furthermore add support to Gathercole and Pickering's (2000) finding of larger WM deficit in children with low maths, or low maths and English attainment.

In relation to reading achievement of the below average group, as previously mentioned, half (eight), of the group were not achieving the National Standard for their age and year in both maths and reading, and only two more were not achieving in reading only (63% in total). Achievement in reading has found to be best predicted at 11 years of age by verbal and visuo-spatial WM ability (St Clair-Thompson, & Gathercole, 2006). Verbal STM has also been implicated as deficient in children with reading difficulties (Gathercole, Alloway et al., 2006). Therefore low reading achievement in the below average academic group could also explain the significant difference in scores across three of the components of WM.

WM Profile of the Below Average Academic Group

The WM profile of the below average academic group was similar but different to previous research. Firstly, the present study found that verbal WM and visuo-spatial STM for the below average group to have scores that were the most impaired, albeit, just slightly more so than verbal STM scores. This finding corroborates previous research that children failing to make academic progress have poorer verbal WM (Alloway, Gathercole, Kirkwood & Elliot, 2009), poorer verbal STM and WM (Gathercole, Pickering, Knight et al., 2004), and poorer verbal WM and visuo-spatial STM (Gathercole and Pickering, 2000). Additionally, for the below average academic group in the present study, similar scores in verbal STM and visuo-spatial STM supports the theory that as children develop they assign verbal labels to visual information and use verbal rehearsal to assist recall thereby having optional access to the phonological loop (Baddeley & Hitch, 1974).

Gathercole and Pickering (2000) surmised that the visuo-spatial STM subtests they used in their study may possibly draw more on central executive resources than other visuo-spatial STM measures. This argument could also apply in the present study as the verbal WM measures Gathercole and Pickering (2000) used were the verbal WM subtests presently used, and the scores between verbal WM and visuo-spatial STM in the present study were similar to each other, at least in the below average academic group. Furthermore, for the below average academic group, the block recall subtest in the present study received the lowest standard score for the visuo-spatial STM component. This test is static in nature but there is an arrow that slowly moves across the computer screen pointing in sequence to the blocks to be recalled. This could be viewed as making the task somewhat dynamic in nature, and the participant could be selectively concentrating on watching this arrow move as well as viewing the blocks. This subtest could be drawing more on central executive resources than purely STM storage (Alloway et al., 2006).

In the present study visuo-spatial WM performance remained relatively superior to the other component composite scores of the below average academic group. This also seemed to be the case for the average academic group. One possibility for this could be the underlying theory of domain generality versus specificity of WM - higher visuo-spatial composite WM scores than others could be viewed as this construct being separable; using domain specific resources, rather than central executive domain general resources, at the ages of 9 – 11 years (Alloway et al., 2006).

Another simpler explanation again, may be to look at the visuo-spatial STM and WM tasks used in the AWMA-L. Dynamic tasks are harder to recall than static tasks (Pickering et al., 2001). It has already been mentioned that the block recall task could well appear somewhat dynamic in presentation. It could also be argued that the other two remaining visuo-spatial STM tasks in the AWMA-L have a dynamic element to them as well. The dot matrix task shows a red dot flash up on a grid inside different boxes (locations) in longer sequences, until recall becomes inaccurate. Watching this task shows a degree of movement. Mazes memory task, is static in presentation, however the child may observe the path in the maze by tracking their eyes from the beginning to end of the path. All of the visuo-spatial WM tasks are presented statically. The conclusion here is that although the tasks are measuring visuo-spatial STM and WM, they are also dependent on static or dynamic presentation and processing. Possibly the visuo-spatial STM tasks were more dynamic in presentation or processing, and the visuo-spatial WM tasks appeared more static in presentation to the participants. The difference in presentation format or processing, therefore, could have caused the visuo-spatial STM tasks to be more difficult to be recalled, and the visuo-spatial WM tasks easier to be recall in both academic groups, supporting Pickering et al.'s (2001) finding.

Compared to the norms for the AWMA, the below average academic group's mean aggregated standard composite scores fell into the average WM range for children in their age range. This finding is different to that of Alloway, Gathercole, Kirkwood, Elliot (2009a) who found that mean standard scores across all components in their sample were between one to two standard deviations below the mean for children with a median age of nine and a half. Again this discrepancy could be due to sampling differences; Alloway, Gathercole, Kirkwood, Elliot's (2009a) sample was made up of 53% who had unspecified special educational needs. Furthermore a point worth remembering is one emphasised by Alloway (2007), that there is large variation in WM abilities of children, with a range of five years of WM development within a typical class of 30 children.

One of the aims of this study was to explore the association between academic under achievement and WM. Therefore any deficit in scores across any of the four WM components measured by the AWMA-L was included into the low WM group. Previous research has found that WM is more compromised than STM in groups with low WM (Alloway, Gathercole, Kirkwood, & Elliot, 2009a; Gathercole & Pickering, 2000; Alloway, Gathercole, Pickering, Knight et al., 2004). The present study confirmed this finding however; STM was almost as equally impaired as verbal WM in the below average academic group. This appeared to be the case regardless of the area of under achievement in school curriculum tests. This finding highlights that deficits in STM storage should not be overlooked in children making poor academic progress because if a memory trace decays rapidly then it follows that verbal information is not transferred into long term memory (Baddeley & Hitch, 1974) and hinders academic progress (Alloway & Alloway, 2010).

WM Scores and Classroom Behaviour

Significant results were found when comparing WM groups on teacher's ratings on the WMRS. The finding that children with low WM exhibit higher incidences of behaviour related to WM deficits in the classroom corroborates previous research (Alloway, Gathercole, Kirkwood & Elliot, 2009a; Gathercole, Alloway, Kirkwood et al., 2008).

The WMRS ratings in the present study correctly identified a slightly higher percentage (75%) of WM impaired children compared to those found by Alloway, Gathercole, Kirkwood, and Elliot (2009a) and Alloway, Gathercole, Kirkwood et al. (2008), 65% and 67% respectively. Alloway, Gathercole, Kirkwood, and Elliot's (2009a) study, had a mixed sample of children; a WM group, an ADHD group, and a control group. The slight discrepancy between the current study and theirs could be related to difficulties in differentiation of their two impaired groups, as the WMRS did not significantly discriminate between the ADHD and the low WM group in that study. The discrepancy could also lay with the fact that teachers in the Alloway, Gathercole, Kirkwood, and Elliot (2009a) study had to fill out three separate and different rating scales for each child, which could have resulted in overload on the teacher's time and motivation to accurately reflect their observations, thereby not categorising all children accurately.

In the present study only 12% of the average and above WM group were rated as having problem WM behaviour, this also is a similar result to Alloway, Gathercole, Kirkwood et al. (2008) who found 11% in their average WM group. They do caution that the WMRS may misclassify children who are unmotivated, shy, or bored. They suggest that this aspect of the rating scale warrants further research.

WM Scores and Home Behaviour

The WMRS-PC is a rating scale adapted from the WMRS in the hope of enabling parents to rate their child's WM behaviour in the home environment for the current study only. The ratings obtained from the WMRS-PC in the current study helped to illustrate that behaviours related to WM can be identified by parents in the home setting. The WMRS-PC ratings correctly identified 83% of children in the low WM group. This is a higher result than that obtained from teachers ratings on the WMRS. The difference may be due to the WMRS-PC not being normed or standardised, or being constructed and rigorously tested for its psychometric properties. Although the items in the questionnaire were based on the WMRS which is appropriate for a school setting, the items may be reflective of different behaviours or motivations in the home environment. However the current finding establishes that parents are capable of recognising behavioural difficulties in their children, and this result using the WMRS-PC in its current raw form illustrates that ability.

When the mean ratings on the WMRS-PC were compared by academic groups, there was also a significant difference found with the below average academic group being rated as having significantly higher WM behaviours than the average academic group. Classification of the academic groups into problem behaviour or typical behaviour categories using chi square analysis did not find a significant difference. It is uncertain why there is a conflict between these two results. It could be because of the non standardised state of the WMRS-PC. Another explanation for the non significant chi square result could also be because six of the 16 children from the below average academic group had average and above WM abilities, and the WMRS-PC is, after all, attempting to measure WM behaviour and not academic ability. Despite the chi square finding for academic groups, the corroboration in results between these two measures (WMRS and WMRS-PC) highlights the point regarding parental reliability in identification of problem WM behaviours. However, results obtained on the WMRS-PC must be treated with caution.

Other influences on WM: Disorders and Experiences

No parent reported their child as having been diagnosed with a mood disorder, ADHD, or being born before 32 weeks gestation. Only one third of the parents in the present study reported other possible influences on WM. No significant difference was found between the low WM group and the average and above WM groups on the disorders and experiences that were reported, they were spread evenly across these two groups. However mention must be made of the non-significant findings relating to the final hypothesis in the present study.

Language and learning disorders. The only other influences reported in the low WM group, were learning and language disorders. Four out the twelve children in the low WM group had an unspecified learning disorder and one had a language disorder. Four of these children were in the below average academic group and were performing poorly in both reading and maths. Only one of these children was in the average academic group. All of these children reported by their parents to have learning or language disorders also had deficits in either verbal STM or WM, with two of them having additional deficits in visuo-spatial STM. None of them were deficient in visuo-spatial WM. It is difficult to comment on why specific areas of WM were deficient in these children as learning disorders were not specified, and their individual WM profile's differed to each other.

The WM results of these children corroborates research with reading disabled children (Gathercole, Alloway, Willis et al., 2006) in that verbal WM and visuo-spatial STM scores were deficient in two of the children. Perhaps the low scores for STM in three of the children may be related to their performance in reading in that their literacy skills are still being developed (Wagner & Muse, 2006). With regard to maths disorder, the current results conflict with those of McLean and Hitch (1999) who found no association between verbal STM and maths disorder, but did find visuo-spatial WM to be associated. The results may conflict as Mclean and Hitch (1999) restricted their sample to children with maths difficulties, with no combined impairments in reading.

With respect to language disorder there was one child identified, who belonged to the low WM group and below average academic group, this child's WM profile revealed deficits in the verbal WM composite score, with all other composite scores in the average range. This supports previous research that verbal WM is impaired in children with specific language disorder whilst visuo-spatial short term and WM remain comparative to unimpaired children (Hutchinson et al., 2012).This child also scored just on the cut off for impairment on the subtest of non-word recall, which supports previous research that this subtest is a useful marker in the diagnosis of SLI (Archibald, Gathercole, 2006a, Conti-Ramsden Durkin, 2007).

Trauma and TBI. The only five children reported as having sustained trauma or TBI, scored in the average and above range of WM. But what is interesting to make note of is that four out of the five fell into the Below Average academic group. With regard to trauma this result agrees with DePrince et al. (2009) in that trauma exposure may have an impact on academic performance. However DePrince et al.'s (2009) result was in relation to familial trauma, and in the present study the questionnaire did not ask parents to specify what type of trauma the child may have experienced.

In relation to TBI, researchers have found TBI does constrain WM (Gorman et al. 2012; Moran & Gillon, 2004; 2005). The present study found no such relationship. However, it was not investigated presently, how severe the TBI's were, if or how long was a loss of consciousness and when the TBI's were experienced. This information may have shed light as to why there was no relationship between TBI and WM scores.

Limitations and Recommendations for future research

The present study was exploratory in nature and caution must be exercised when considering the results. An important limitation of this study was with the sample size. An error was made in *a priori* sample size analysis before commencing. Unfortunately this error was not noticed until after the data collection had been completed which was very close to the end of the school year. As the sample size was very small, the extent to which results can be generalised is limited.

It would be useful for future research in the New Zealand context to look at increasing the sample size and incorporating a larger and more varied demographic area. The benefits of doing this would firstly address the external validity of any future study. Secondly, a larger study could target looking at variables such as how WM is related to specific areas of under achievement.

This study was cross-sectional in design, it may be of benefit for future research to use a longitudinal design and incorporate interventions such as Cog Med (Klingberg et al., 2005), and track if remediation improves WM and/or academic achievement overtime. A longitudinal design could further assess if any improvements found are enduring. Similarly, it may be beneficial to commence a longitudinal project when children are commencing primary school as this may help identify difficulties earlier.

Socio-economic variables were not investigated in the current study. It may be useful to investigate this variable in New Zealand to ascertain if there is a relationship in a local context between; WM, academic achievement, and SES. Furthermore, future research could also investigate if SES is also related to the type of WM measures used.

No child was reported by their parents as having been diagnosed with mood disorders in the current study. Researchers have found that this variable has an influence on WM (Brookes, 2010; Grimley et al., 2008). Future research could look at obtaining information from parents or teachers about sub clinical levels of mood disorders; this maybe more informative if formal diagnosis has not been made.

The WMRS-PC was a tool adapted specifically for the current study. It was helpful to the author as a preliminary and rudimentary tool to understand WM behaviour in the home. It may be advantageous to have such a measure researched and developed, preferably into subscales, to assist researchers in the future and help parents understand their children's difficulties.

Participation issues. The present study was initiated in the school at the beginning of the third to last week of term three. The third term had been very busy for the year five and six students, with a lot of extracurricular activities occurring. For instance, rehearsals and preparation for an end of term school production held in the second to last week of the term had been taking place disrupting student's normal classroom activities over a period of weeks. Also many children were involved in inter-school sports tournaments during school time in the last three weeks of the school term. Besides the children being very busy themselves during the term a higher than normal volume of paper notices were being sent home with children to be given to their parents to read, sometimes on a daily basis. As the information sheets and consent forms formed part of the paper work that children were taking home at this time, it was thought that it was highly possible that forms could have been; lost in the plethora of paper and thrown out, forgotten, or students and parents could have been too busy due to goings on in the school as described above and in their own family lives.

Practical Implications

Finding an association between academic achievement and WM maybe informative to educators. Identifying specific WM deficits may help teachers understand where specific weaknesses are located for individual children; verbal and/or visuo-spatial storage and/or processing. This in turn will assist teachers to identify which learning practices and procedures will need to be targeted and modified in order to make learning episodes more productive for such individual children. It may also be conducive to utilise WM assessments early in primary aged children for the abovementioned reasons. Measures such as the ones used in the present study are available to educators to help identify WM difficulties. Both the AWMA and the WMRS are easy to use, administer, interpret and are time efficient.

Summary and Conclusion

The first aim of the present study was to examine the prevalence of low WM in a sample of a year five and six students. A related aim was to examine age related WM growth. The third aim was to examine WM and its relationship to academic achievement in reading and maths in the New Zealand school curriculum. The fourth aim was to investigate low WM and its relationship to teacher and parent behaviour ratings. The final aim was to investigate if children with low WM experienced other influences on WM such as: trauma or TBI, or are diagnosed with mood disorders, language or learning disorders, or ADHD, more often than children with intact WM.

It was found that 20% of children assessed were classed as having low WM, with 63% of the below average academic group having low WM. The below average academic group was found to perform significantly more poorly on WM assessments than the average academic group. Accordingly, the low WM group were rated significantly higher than the average and above WM groups as having behaviours relating to WM deficits as assessed by their teachers and parents. There was no significant difference found between WM groups on reported incidence of experiences or diagnosis of other influences on WM.

These findings support previous research on the link between WM and academic achievement. However the sample size was small and confined to one school so results must be interpreted with caution. Further research could assist in ascertaining if the link between WM and academic achievement can be separated out into specific areas of under achievement in the New Zealand school curriculum. Future research could also include different variables that maybe associated with WM and academic achievement, and investigate these relationships using larger samples, more schools, and a longitudinal design.

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Appendix I

MASSEY UNIVERSITY

Working memory in children and its relationship to academic achievement and behaviour.

Students Information Sheet

My name is Jill Colenso-Mita, and I am a student at Massey University. I am doing a study at your school to learn about how memory is linked to how children learn and act in the classroom and at home. Professor Janet Leathem is helping me.

I need to choose some children in year 5 and 6 that have done okay on their school tests and some that haven't done so well.

If you want to take part in my study and your parents say it is okay, AND you get chosen, then I will need to spend about 45 minutes with you doing some tasks on a computer during school time. These tasks aren't like school tests and are quite fun, they are made especially to measure memory. I will also be asking your parents/caregivers, and teacher to fill in a questionnaire about your learning and memory in class and at home.

Some of you might know me because I have children that go to this school and you may have seen me there. So if you don't feel okay about me knowing about how you're doing with your school work or memory, that's fine, **you don't have to be in the study if you don't want to.** But just so you know, I can't talk about your school work to anyone else only my Professor and she's all the way down in Wellington, she also isn't allowed to tell anyone about your school work or memory either. Also, any information and answers you give me in the study are private so I can't tell the principal or your teacher, or anyone else.

Just so you understand, you **can choose to help** me and be in the study if you want. You can also **choose not to help**. If you do choose to help, but then change your mind later when we are doing the computer memory tasks then that's okay too.

If you and your parents decide you can help with the study, please get your parents to sign the permission slip and bring it back to school by the date written on the consent form.

If you get chosen to help me with my study, I will let you know soon. If you don't get chosen I will come to your class and let everyone know, who hasn't been chosen.

As a sign of my appreciation for the time you have taken to read this information and returning the permission forms, you will go in the draw to win a family pass to the movies.

If you or your parents have any questions about the study at anytime just give me a ring I will be happy to answer them.

Yours sincerely,

Jill Colenso-Mita
Ph: (0800) 351 572
Email:gecko067@xtra.co.nz

Janet Leathem PhD,
Professor of Neuropsychology,
Clinical Programme Co-ordinator,
Wellington Campus,
Massey University.
Email:J.M.Leathem@massey.ac.nz
Phone: (04) 801 5799 ext: 62035

Appendix II

MASSEY UNIVERSITY

Working memory in children and its relationship to academic achievement and behaviour.

Parents Information Sheet

Dear Parents/Guardians,

My name is Jill Colenso-Mita, I am a graduate psychology student at Massey University. As part of my Master's degree I am undertaking a study that is looking at how working memory is related to; school achievement in numeracy and literacy, as well as behaviour in the classroom and at home. The study is to be conducted with year 5 and 6 students at School. I am writing this letter to invite you and your child's participation. Professor Janet Leathem is overseeing this project.

The first part of the study will involve selecting two groups of children from the school database: those who have achieved average scores, and those who have achieved below average scores on tests of numeracy and literacy, for national standards in the New Zealand curriculum. If you give permission for your child to participate, the school principal, Mr who has access to the database, will determine if your child falls into one of these two groups. From this point, your child may go on to be selected for the study if they are achieving within one of these two groups. Selection into the study from this point on is organised by the researchers using random selection methods. No one will be told which group a particular child has been selected from.

Students selected will be asked to spend about 45 minutes with me, at school, doing various tasks on a computer. These tasks are designed specifically to measure some aspects of memory that are related to learning, and are usually quite fun for children. If you wish for your child to participate and they are selected, but you would like them to be assessed outside of school time i.e.; lunchtime or after school, please contact me for this alternative time to be arranged.

If your child is selected for the study, they will be given another letter to bring home to you explaining briefly what will happen next. You will then also be asked to complete a questionnaire about your child's learning, memory and general behaviour and to return it in the stamped envelope provided. The questionnaire will take about 15 minutes to complete. Your child's teacher will also be asked to complete a similar questionnaire about their behaviour in the classroom. If your child has not been selected for the study, they will be told this in a general class announcement.

I'd also like you to know that I am part of the school and local community as I live here and my two youngest children currently attend Primary. Please be assured again that participation is completely voluntary and that my knowledge of your child's achievement in numeracy and literacy, and the data collected on their memory tasks are bound by strict rules regarding confidentiality. No one but the researchers will have access to this information. Your child's identity on any forms will be protected. All information obtained from the students over the course of the study will be kept secure by way of locked filing cabinets, of which only the researchers have access to. The data from the computerised test will be protected by a password on the computer. None of the information gathered from the questionnaires or the computer tasks will be made available to the school. In the research write up there will be no way of identifying individually yours or your child's responses. All data, responses, and questionnaires will be destroyed at the end of the study.

If you do decide to take part in the study and let your child take part, thank you in advance. You have the right to refuse to answer any particular questions and the right to withdraw from participating at anytime. You also have the right to decline yours and your child's participation in this study.

Parents, could you please speak with your children briefly about this study before filling in any consent forms just to ensure they understand, and that they know it is voluntary and that all the information I might gather will be kept confidential. I will also check again with the children before the memory assessment commences if they would still like to participate or not.

Attached is the permission/consent form, please indicate by circling the appropriate response to **allow or not allow** you and your child to participate in the study. Please return this form to your child's teacher by the date written on the form.

As a sign of my appreciation for the time you have taken to read this information and returning the permission forms, your child will go in the draw to win a family pass to the movies.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 12/34. If you have any concerns about the conduct of the research, please contact Dr Nathan Matthews, Chair, Massey University Human Ethics Committee: Southern B, telephone 063569099 ext 80877, email: humanethicsouthb@massey.ac.nz.

If you have any queries or concerns about this project please do not hesitate to contact Jill on the details below.

Yours sincerely,

Jill Colenso-Mita
Ph: (0800) 351 572
Email:gecko067@xtra.co.nz

Janet Leathem PhD,
Professor of Neuropsychology,
Clinical Programme Co-ordinator,
Wellington Campus,
Massey University.
Email:J.M.Leathem@massey.ac.nz
Phone: (04) 801 5799 ext: 62035

Appendix III

MASSEY UNIVERSITY

Working memory in children and its relationship to academic achievement and behaviour.

Teacher Information Sheet

Dear Teacher,

My name is Jill Colenso-Mita, and I am conducting a study looking at how working memory is related to; school achievement in numeracy and literacy, as well as behaviour in the classroom and at home, for children in years 5 and 6. This research is in partial completion of a Master of Arts degree (Psychology). Professor Janet Leathem is overseeing this project.

Some students in your class have been selected to participate in this study.

I am inviting you to take part in this phase of the study. As far as your involvement goes, we would like you to fill out a brief questionnaire that will take approximately 5 minutes to complete for each student in your class that is participating in the study. The questionnaire asks questions about the student's classroom behaviour.

Your responses on the questionnaires are completely confidential. All information obtained over the course of the study will be kept secure in locked filing cabinets, of which only the researchers have access to. In the research write up there will be no way of identifying your individual responses. All data, responses, and questionnaires will be destroyed at the end of the study.

As I am a parent of children that attend School some of the year 5 and 6 teachers may know me. Please do not feel obliged to participate in this study because of this, participation is completely voluntary.

You have the right to decline participation in this study. If you do decide to take part, thank you in advance, but you also have the right to refuse to answer any particular questions and the right to withdraw from participating at anytime.

A summary of the study will be available to you shortly after the study is completed. If you would like a copy please circle "Yes" for receiving a summary on the accompanying consent form. Otherwise a presentation will be made to staff taking part in the study.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 12/34. If you have any concerns about the conduct of the research, please contact Dr Nathan Matthews, Chair, Massey University

Ethics Committee: Southern B, telephone 06 350 5799 x 8729, email: humanethicsouthb@massey.ac.nz.

If you have any queries or concerns about this project please do not hesitate to contact me at the details provided below.

Yours sincerely,

Jill Colenso-Mita
Ph: (0800) 351 572
Email:gecko067@xtra.co.nz

Janet Leathem PhD,
Professor of Neuropsychology,
Clinical Programme Co-ordinator,
Wellington Campus,
Massey University.
Email:J.M.Leathem@massey.ac.nz
Phone: (04) 801 5799 ext: 62035

Appendix IV

MASSEY UNIVERSITY

Working memory in children and its relationship to academic achievement and behaviour.

Parents Letter – Selection

Dear Parents/Guardians,

My name is Jill Colenso-Mita, not long ago you gave consent/permission for your child and yourself to participate in a study on memory and learning at Primary School, thank you very much.

This letter is to let you know that your child has been selected to participate in the study. Very soon I will be spending approximately 45 minutes with each child individually during school time. They will be completing some computer tasks, which have been designed to measure the part of memory which assists learning. These tasks should be quite enjoyable for the children to complete. Alternatively, if you would like your child to be assessment at a different time outside of school hours (or at lunchtime), please do not hesitate to contact me to arrange this.

I also ask that you complete the short questionnaire (enclosed) that asks questions about your child's learning, and general behaviour at home. The questionnaire should take no longer than 15 minutes to complete and can be returned in the stamped address envelope enclosed in the letter. Your child's teacher will also be asked to complete a similar questionnaire from a classroom perspective.

As this is a research project and the relationship between academic achievement and working memory is as yet unclear, individual feedback cannot be given. However, if you would like a copy of the overall results and a summary at the end of the study, please put a tick in the box at the end of the Parent Questionnaire form. There will also be a summary presentation of the results held at the school. If you are interested in attending you will be notified of the date once this had been arranged.

All information obtained from you and your child over the course of the study will be kept securely in locked filing cabinets, to which only the researchers have access to. The data from the computerised test will be protected by a password on the computer. None of the information gathered from the questionnaires or the computer tasks will be made available to the school or anyone else, and will only be available to the researchers. In the research write up there will be no way of identifying yours or your child's individual responses. All data, responses, and questionnaires will be destroyed at the end of the study.

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 12/34. If you have any concerns about the conduct of the research, please contact Dr Nathan Matthews, Chair, Massey University Human Ethics Committee: Southern B, telephone 06 350 5799 x 8729, email: humanethicsouthb@massey.ac.nz.

If you have any queries or concerns about this project please do not hesitate to contact me on the details below.

Yours sincerely,

Jill Colenso-Mita
Ph: (0800) 351 572
Email:gecko067@xtra.co.nz

Janet Leathem PhD,
Professor of Neuropsychology,
Clinical Programme Co-ordinator,
Wellington Campus,
Massey University.
Email:J.M.Leathem@massey.ac.nz
Phone: (04) 801 5799 ext: 62035

Appendix V

MASSEY UNIVERSITY

Working memory in children and its relationship to academic achievement and behaviour

Consent Form

Parent and Child Consent Form

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

Please fill out this form and return it to school by Thursday 27th September, 2012.

I **give / do not give** consent for my child ______________________________ (child's name)

in _______(Room) to take part in this research project as outlined in the Information Sheet given to me.

By giving consent, I agree that the Principal can access the school database for the purposes of identifying if my child fits the criteria for the study. I also agree to participate in this study under the conditions set out in the Information Sheet.

Signature:

....

Full Name:

....

Date: ....

Relationship to child: ....

....

Appendix VI

MASSEY UNIVERSITY

Working memory in children and its relationship to academic achievement and behaviour.

Consent Form

Teacher Consent Form

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

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

Full Name:
……………………………………………………………………………………………………

Date: ……………………………

I would like to receive a summary of the results of the study Yes/No (circle one)

Please send a summary of the results to the following address/email:

……
……
……
……

Appendix VII

WORKING MEMORY RATING SCALE – Record Form

The table below provides descriptions of common classroom behaviours. Please identify how typical each behaviour is of this child by circling the appropriate number in one of the four right-hand columns. Only one number should be selected for each behaviour.

	NOT TYPICAL AT ALL	OCCASIONALLY	FAIRLY TYPICAL	VERY TYPICAL
1. To move on to the next step in an activity, needs frequent prompts by teaching staff	0	1	2	3
2. Puts hand up to answer a question but forgets what s/he intended to say when asked	0	1	2	3
3. Frequently asks for help	0	1	2	3
4. Abandons activities before completion	0	1	2	3
5. Does not respond, or is reluctant to answer (e.g. shrugs shoulders or nods head) when asked direct questions	0	1	2	3
6. Mixes up material inappropriately, e.g. incorrectly combines parts from two sentences rather than reading each one accurately	0	1	2	3
7. Frequently stops during lengthy activities or those involving multiple steps	0	1	2	3
8. Needs regular reminders of each step in a written task	0	1	2	3
9. Forgets how to continue an activity that was previously started, despite teacher explanation	0	1	2	3
10. Benefits from continued teacher support during lengthy activities	0	1	2	3
11. Requires support for effective use of memory aids such as useful spellings and number lines	0	1	2	3
12. Loses his or her place in complicated activities	0	1	2	3
13. Incorrectly repeats the same response, e.g. by writing the same word twice in a sentence	0	1	2	3
14. Does not follow classroom instructions accurately, e.g. carries out some but not all steps in an instruction	0	1	2	3
15. Raises hand but gives inappropriate or incorrect answers	0	1	2	3
16. Is making poor progress in literacy and maths	0	1	2	3
17. Unable to explain what s/he should be doing in a particular activity when asked	0	1	2	3
18. Not able to focus during activities	0	1	2	3
19. Requires regular repetition of instructions	0	1	2	3
20. Depends on neighbour to remind them of the current task	0	1	2	3
			Total	

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Appendix VIII

Working Memory Rating Scale for Parents/Caregivers

The table below provides descriptions of behaviours to do with general activities at home and homework. Please identify how typical each behaviour is of this child by circling the appropriate number in one of the four right-hand columns. Only one number should be selected for each behaviour.

	NOT TYPICAL AT ALL	OCCASIONALLY	FAIRLY TYPICAL	VERY TYPICAL
1. Frequently asks for help when doing homework	0	1	2	3
2. Needs to be reminded of instructions for homework tasks even when previously given instructions	0	1	2	3
3. Benefits from continued parent support during lengthy homework activities	0	1	2	3
4. Needs support to use dictionaries and other learning aids	0	1	2	3
5. Easily distracted during challenging homework/activities	0	1	2	3
6. Does not complete homework	0	1	2	3
7. If asked a question forgets what s/he intended to say.	0	1	2	3
8. When asked to do a task with multiple steps will abandon task.	0	1	2	3
9. When asked to do a task with multiple steps will need reminding of each/some steps.	0	1	2	3
10. Does not follow instructions accurately e.g., carries out some but not all steps.	0	1	2	3
11. Requires regular repetition of instructions.	0	1	2	3
12. Asks family members to remind them of current tasks asked of them.	0	1	2	3
13. Asks what's just happened in a programme/movie they have been watching with others.	0	1	2	3
14. When asked to repeat instructions or what's just been said, they give incomplete information or say they don't know.	0	1	2	3

Please turn over to the next page....

Please circle your answers

1. Has this child ever sustained a head injury that was serious enough to; cause a loss of consciousness/concussion/loss of memory/require medical attention?

Yes No

2. If you answered Q1 "yes" how many times has this occurred?

1 2 3 4 5+

3. Has this child ever been diagnosed with any of the following:

- **Language, reading, writing or maths disability** **Yes No**
- **Mood Disorder i.e. Depression or Anxiety** **Yes No**
- **Attention Deficit/ Hyperactivity Disorder** **Yes No**
- **Born before 32 weeks gestation** **Yes No**
- **Other: please state**

4, Is this child taking a course of medication that may affect their behaviour (excluding cold or flu medication)

Yes No

If you answered Yes to Q3, please state the name of the medication and how long this child has been taking it? ____

5, Has this child ever been subjected to/or witness to any other type of trauma i.e., car accident, that was sufficient to cause harm to the child?

Yes No

Would you like a summary of the study after it has been completed? **Yes No**

If yes please supply email/address you would like the summary sent to:

____

Alternatively would you like to attend a presentation of the results? **Yes No**