THE RELATIONSHIP BETWEEN CHILDREN'S READING COMPREHENSION, WORD READING, LANGUAGE SKILLS AND MEMORY IN A NORMAL SAMPLE

Submitted by

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SUMMARY

The current study aimed to develop a model of reading comprehension for children in middle primary school. As part of this overall aim there was a particular focus on the contribution of different types of memory to reading comprehension. The variables selected for consideration were identified from the child and adult literature and were of three types: word reading, language, and memory. The sample comprised 180 primary school children in grades 3-5 recruited from two primary schools. Their ages ranged from 8 years 7 months to 11 years 11 months.

The reading comprehension measure was in a multiple-choice format with the text available when answering the questions. The five word reading measures were phonological recoding, orthographic processing, text reading accuracy, text reading speed, and a measure of exposure to print and reading experience. It is recognised that, although exposure to print is closely associated with word reading skills, it is not a direct measure of word reading. The language measures were oral comprehension, receptive vocabulary and receptive grammatical skills. The memory measures included measures of verbal and visuospatial short-term memory, measures of verbal and visuospatial working memory, a measure of the ability to inhibit irrelevant information from working memory and a measure of longer term verbal learning and retrieval. Correlational and hierachical multiple regression analyses were used to extrapolate the relationships between and among these variables.

The results revealed that, after controlling for age and general intellectual ability, the word reading and the language variables had a much stronger relationship with reading comprehension than the memory variables. The strongest independent predictors of reading comprehension were orthographic processing and oral comprehension. An additive combination of these two variables provided a more parsimonious model of reading comprehension than other models under consideration. It was concluded that for the age range in this study, language and word reading skills are the main predictors of reading comprehension and that the different types of memory do not make major contributions to reading comprehension.

STATEMENT OF AUTHORSHIP

Except where reference is made in the text of the thesis, this thesis contains no material published elsewhere or extracted in whole or in part from a thesis or any other degree or diploma.

No other person's work has been used without due acknowledgment in the main text of the thesis.

This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

All research procedures reported in the thesis were approved by the Faculty of Science, Technology and Engineering Human Ethics Committee (FHEC Application 00/R13).

Deborah Goff Date

CHAPTER 1. PREAMBLE

1.1 Background

Reading comprehension entails the successful extraction of meaning from written material. The objective of reading is comprehension and it would generally be agreed that comprehension is the ultimate goal of teaching children to read independently. In the early primary school years there is a strong emphasis on decoding or word reading. Once word reading skills have been attained however, comprehension becomes the key to learning. Most learning in secondary and tertiary education relies on comprehension of the written word. Even outside of the educational arena, comprehension is an important tool, which allows individuals to participate effectively in society. For example, without comprehension skills, individuals are unable to grasp the complexities of current affairs in the newspaper or make sense of the barrage of information on the internet. Reading comprehension is therefore an extremely valuable skill and is a worthy topic of research.

Although there is not as much research on reading comprehension as reading decoding, there is still a reasonably large literature on reading comprehension both in adults and children. Much of the developmental literature has tended to focus on co-occurring deficits in poor comprehenders with adequate word reading skills. There has not been as much emphasis on reading comprehension in normal samples and there is no generally accepted developmental model of reading comprehension.

Chapter 1 Preamble

Studying the predictors of reading comprehension in normal samples is important since it has the potential to provide the basis of future educational programs to enhance the comprehension ability of the majority of children whose comprehension ability falls within a normal range.

Traditional developmental models of reading comprehension, such as the *simple view*, which was developed by Gough and Tunmer (1986), and tested by Hoover and Gough (1990) in a longitudinal sample of children in grades 1 to 4, assume that reading comprehension is a skill which is grafted onto oral (or listening) comprehension when children start to read. From this perspective, reading comprehension skills can be predicted from the product of oral comprehension and word reading skills. In the *simple view*, word reading skills are conceptualized as phonological recoding. Phonological recoding is the ability to translate letters and letter patterns into a phonological (sound-based) format and can be measured by nonword (or pseudoword) reading.

There is little doubt that there is a high correlation between reading comprehension and both oral comprehension (Cornoldi, De Beni, & Pazzaglia, 1996; Nation & Snowling, 1997) and word reading skills generally (Yuill & Oakhill, 1991). Both oral comprehension and word reading are strong predictors of reading comprehension in normal samples, and, the two variables combined may account for a substantial amount of variance in reading comprehension skills. There is some debate however on whether a multiplicative or an additive combination of oral comprehension and word reading skills provides a better model of reading comprehension (Dreyer & Katz, 1992; Joshi & Aaron, 2000).

Comprehension is heavily dependent on word reading skills in the early primary school years since children cannot comprehend what they are unable to read (Storch & Whitehurst, 2002). Research suggests however that reading comprehension becomes less dependent on word reading skills after the initial primary school years (e.g., Roth, Speece & Cooper, 2002 and Storch & Whitehurst, 2002). The current research focuses on reading comprehension in the middle to latter primary school years, when word reading skills are well established.

In Hoover and Gough's (1990) original study in which the *simple view* was put to the test, reading comprehension skills were assessed by children's memory for the contents of the text after children had completed one read of the test material and the text had been removed. This contrasts with what normally happens when a child reads to him/herself with the text available at all times and ambiguities can be clarified by re-reading parts of the narrative. Reading comprehension skills are frequently assessed in the absence of the text, which places heavy demands on encoding processes (i.e. short-term memory).

Oral comprehension places similarly heavy demands on short-term memory since information must be encoded immediately or lost. Reading comprehension with the text available may be different to oral comprehension, in that reading comprehension is less dependent on encoding processes and more dependent on language skills, the amount of previous exposure to print and the ability to retrieve material from long-term memory.

1.2 Research Aims

The central aim of the current research was to investigate the abilities that make independent contributions to reading comprehension when the text is available, in a large sample of children in grades 3 to 5 when reading is well established, and to develop a model to account for children's reading comprehension in this context.

The variables selected for possible inclusion in the model fall into three broad categories: word reading, language skills and memory. While word reading skills are certainly an essential prerequisite for reading comprehension, it is not clear whether phonological recoding or orthographic skills make a greater contribution to reading comprehension when children have past the early stages of learning to reading. It is also unclear whether reading speed adds to the prediction of reading comprehension beyond word reading accuracy.

Like word reading, it is generally accepted that language skills are a prerequisite of reading comprehension. There is some evidence to suggest that language skills, particularly semantic processing ability, may be the most important predictor of reading comprehension (Nation, 2001; Roth et al., 2002; Stothard & Hulme, 1996). In traditional models, such as the *simple view*, reading comprehension is conceptualized as requiring the same skills as oral comprehension but with the inclusion of word reading skills. The extent to which reading comprehension recruits the same skills as oral comprehension is debatable however. It may be possible to formulate a more elaborate model incorporating specific language skills such as semantic ability or grammatical and syntactic skills.

Although there is general agreement that word reading and language skills make an important contribution to reading comprehension, there is much less consensus about the role played by memory. The conceptualization of WM and how it is measured is a pivotal methodological issue in this debate. The types of task used to measure WM may be critical since there is a suggestion that the relationship between reading comprehension and working memory may be underpinned by language skills, (Nation, Adams Bowyer Crane, & Snowling, 1999).

Compared with WM, the role of long-term memory (LTM) in reading comprehension has been somewhat neglected. Although, as Ericsson and Kintsch (1995) point out, reading comprehension must involve LTM since readers have to maintain and integrate large chunks of information. Short-term memory (STM), (sometimes referred to as immediate memory), does not provide sufficient storage capacity for such skilled complex activities.

A further aim of the current research is to establish whether the type (STM, WM, LTM), mode (verbal versus visuospatial) or nature of the stimuli (numeric versus word) affects the strength of the relationship between the memory measure and reading comprehension. These issues will be addressed by incorporating a wide range of memory measures and the study is unique in this respect. The memory measures include STM, WM and a measure of longer-term learning and retrieval. There are both verbal memory tasks (some with numeric and others with word stimuli) and visuospatial memory tasks. One of the problems in interpreting research suggesting that reading comprehension is associated with verbal but not visuospatial WM (e.g., see Seigneuric, Ehrlich, Oakhill, & Yuill, 2000) is that the tasks have very different processing and storage requirements. In the current study, the visuospatial WM task, triplet block span, was specifically designed to have similar processing and storage demands to the verbal WM task, triplet number span.

1.3 Thesis Outline

In the following review of the literature on reading comprehension Section 2.1 focuses on models of reading comprehension, documenting the component processes involved. This is used to justify the selection of variables for inclusion in the current study. The variables are divided into three main categories: word reading, language skills and memory. The relationships between reading comprehension and the word reading, language, and memory variables are considered in Sections 2.2-2.4 respectively. Section 2.5 is devoted to the conceptualization of reading comprehension in the current study and the selection of an appropriate measure. Finally, in Section 2.6 there is a summary of the aims of the study.

The method for the current research is outlined in Chapter Three within three main sections. The Method commences with a description of the sample, followed by a detailed description of the measures used and the procedure.

The results are documented in Chapter Four. Following the presentation of both correlations and partial correlations (controlling for age and general intellectual ability) showing the inter-relationships between the variables, a series of hierarchical regression analyses are reported, with a view to identifying the strongest predictors of reading comprehension from amongst the word reading, language and memory variables. The results of these analyses are used to formulate a model of reading comprehension. The strength of this model is compared with both additive and multiplicative variants of traditional models, such as the *simple view*, which incorporate oral comprehension and phonological recoding.

A discussion of the findings follows in Chapter Five. The implications of the findings for each of the types of predictor variable are presented within three sections: word reading, language skills, and memory. This is followed by sections on the implications of the findings for models of reading comprehension and the implications for the development of remediation programs aimed at children in the middle to late years of primary school. Finally, there is a detailed summary of the findings.

CHAPTER 2. INTRODUCTION

2.1 Models of Text Comprehension

In contrast to oral comprehension, which involves interpreting the meaning of spoken language, reading comprehension is the extraction of meaning from written text. In the adult literature cognitive scientists view comprehending (or understanding) a text as a process of constructing a coherent memory representation. This representation has been referred to as a *mental model* (Johnson-Laird, 1983) or a *situation model* (Graesser, Singer, & Trabasso, 1994; Morrow, Greenspan, & Bower, 1987). The representation is believed to be constructed of a network of related propositions. The proposition has been adopted as a basic unit of meaning and represents “idea units” in a message (Lorch & van den Broek, 1997; Singer, 1994). For example, the sentence, “The car came to a halt”, contains two propositions; that is, CAR, STOPPED. It is assumed that readers incorporate propositions into their memory representations as they read (Kintsch & van Dijk, 1978).

In their seminal paper on text comprehension Kintsch and van Dijk (1978) differentiated between micro and macro levels of understanding text. The micro level refers to the local level of understanding; that is, understanding the text on a sentence by sentence basis.

Comprehension at a macro-level, on the other hand, involves constructing a schematic representation of the overall gist of the content. The verbatim representation of a sentence is therefore soon discarded after the meaning has been extracted and the most important representation is that of the gist of the content (Gernsbacher, 1990).

Many different processes have been identified as being important components of creating a representation of a story or text (Just & Carpenter, 1980). These include word recognition and lexical access, semantic activation and inference making, case role assignment, information integration and maintaining a representation in WM.

Word recognition and lexical access are involved in the first stage of the comprehension process. Word recognition and lexical access involve transforming the word code into a semantic format (Just & Carpenter, 1980). The visual features of the word are used to activate the representation of the word. Lexical access is complex in the sense that some words have more than one meaning. Words that are used more frequently will have a higher level of activation and, in the same way, the more common interpretations of words will have higher activation levels and will therefore be accessed faster (Just & Carpenter, 1980). However, the preceding semantic and syntactic context helps the reader select the appropriate meaning of a word. It has been found that although multiple meanings of a word are initially activated, only one meaning remains activated after a few hundred milliseconds. The immediate selection of one interpretation over another limits the amount of information that has to be maintained in WM.

Semantic activation and inference making are important components of reading comprehension. Once the representation of the word has been sufficiently activated, its corresponding semantic concept is accessed. Each semantic concept is part of a small semantic network in which the nodes of the network are the possible meanings of the word, the semantic and syntactic properties of the meanings and information about the contexts in which they occur. A semantic concept is represented in WM as an abstract predicate, defined by its relationship to other predicates.

A concept does not necessarily have to be encountered in the text to be activated (Patterson & Hodges, 1995). A concept can be made available in WM via spreading activation through the semantic and episodic knowledge base. For example, “bullet” might activate “gun” in a murder mystery. Lorch and van den Broek (1997) and Trabasso and Suh (1993) have suggested that readers systematically identify and represent causal relations among events in the text as an aid to comprehending a narrative. In order to do this readers must often go beyond the literal meaning of a text and make inferences based on prior knowledge and personal experience (Long, Seely, Oppy, & Golding, 1996; Mannes & St. George, 1996). Readers with a more developed semantic system will be more adept at making inferences from text in general. Also, readers who have domain specific knowledge will be better placed to make inferences from reading matter on their area of expertise (Adams, Bell & Perfetti, 1995; Schneider, 1993).

Another aid to comprehension is the assigning of case roles which is an aspect of grammatical knowledge (Just & Carpenter, 1980). The assignment process relies on heuristics based on word meaning and information about the prior semantic context. Words are classified according to semantic cases such as agent, recipient, location, time, manner, instrument, action or state. Grammatical context and syntax also serve as useful aids to assigning case roles and facilitating comprehension. For example, in the sentence, Henry went to the _____to pick up the _____ , the semantic and syntactic context leads the reader to the conclusion that an acceptable version of the sentence is, "Henry went to the shop to pick up the bread", rather than, "Henry went to the bread to pick up the shop".

In order to extract meaning from text a reader must integrate new information with previously presented information or alternatively, with knowledge retrieved from LTM (Just & Carpenter, 1980). Several strategies are used to try and integrate information in the text into a coherent whole. One strategy is to check whether new information encountered is related to the information already in WM. Another strategy is to search for specific cues in the new sentence that relate to previous information. Often these cues are just a repetition of previously presented information, or alternatively, they can be literary devices like intersentential connectives, such as anaphoric reference. Anaphoric reference refers to the use of words such as “it” “his” “her” or “one”, which have the same referent as a word or group of words previously used in the same narrative; for example “he lost the last *one*” could refer back to “The boy had a *ball”* (Webber, 1980).

The ends of sentences appear to be especially pertinent to integration processes. At these points in the text the reader executes a procedure which has been dubbed “sentence wrap-up” (Just & Carpenter, 1980). During this procedure the reader attempts to resolve all the within sentence ambiguities and to integrate the new material with previously presented information. The integration process allows the chunking of text so that the limited capacity WM system can deal with large segments of prose allowing the gist of the information to be remembered. This means that much of the information that the reader deems to be irrelevant or unnecessary is lost from WM and forgotten.

Working memory is believed to be the tool with which a model of information in the text is maintained. The representation in WM is constantly being updated as a result of the integration process. Working memory resources must therefore be adequate to allow the concurrent storage and processing of information in which information from the text must be maintained until it is transformed into a meaningful narrative format via access to semantic pathways and prior knowledge. It is noted however, that although WM is almost certainly recruited in reading comprehension, deficiencies in

WM may not be crucial when children have access to the text. In this context children may be able to compensate for memory deficiencies by re-reading ambiguous or unclear sections of the text as many times as they like, to aid comprehension.

The above description of the processes involved in reading comprehension suggests that fast and accurate word reading skills, well-developed semantic and syntactic abilities, adequate WM and the ability to store and retrieve verbal information may all contribute to reading comprehension skills.

2.1.1 Developmental Models of Reading Comprehension

There is no generally accepted model of reading comprehension linking the development of reading comprehension in children with the growth of cognitive skills. Traditionally, reading comprehension has been viewed as an ability which is grafted onto oral comprehension when children start to read.

2.1.1.1 Traditional Models such as the Simple View

The close relationship between reading comprehension and oral comprehension skills and between reading comprehension and word reading skills has led to the development of models in which reading comprehension is viewed simply in terms of a combination of oral comprehension and word reading skills (Curtis, 1980; Rubin, 1980). Gough and his colleagues proposed the *simple view* of the proximal causes of differences in reading comprehension ability (Gough & Tunmer, 1986; Hoover & Gough, 1990) which was developed for children in the early stages of reading.

Hoover and Gough (1990) tested the model on children in grades 1-4. In this model, *R = D x C,* where *R* is reading comprehension, *D* is decoding (that is, phonological recoding), and *C* is listening (oral) comprehension. Multiplicative models, such as the *simple view*, predict that the effect of decoding or listening comprehension on reading comprehension is dependent on the reader's level of competence in the other skill. For example, if listening comprehension ability is high but word reading skills are low (or visa versa) reading comprehension will be poor. Each skill is therefore assumed to be necessary but not sufficient for adequate reading comprehension.

Other researchers have proposed that the relationship between oral comprehension and word reading skills is additive rather than multiplicative. For example, Dreyer and Katz (1992) found that the model R = D + C better fitted the data, whereas Perfetti (1977) had previously hypothesized that *Reading Comprehension = Language Comprehension + Decoding + X.* As in the *simple view,* language comprehension (or linguistic comprehension as it is referred to by Gough and Tunmer (1986) is operationalised as the comprehension of oral language. Perfetti (1977) claims that "*X*" is small relative to the other two factors although does not elaborate on what "X" comprises.

Joshi and Aaron (2000) note that much of the evidence in support of a multiplicative component model of reading comprehension comes from research with abnormal populations, such as with children who are hyperlexic or dyslexic. The original sample in which Hoover and Gough (1990) tested the *simple view* was not a normal sample since it comprised English-Spanish bilingual children, some of whom had poor oral English skills. Gough and Tunmer's (1986) multiplicative model ($R = D \times C$) may better describe the relationship between reading and oral comprehension in abnormal populations such as these when one of the components (that is, either oral comprehension or word reading skills) is very poor while the other component may be relatively high. In this instance, an additive model may incorrectly predict a reasonable level of reading comprehension, while a multiplicative model would correctly predict a very poor level of reading comprehension since adequate or superior language comprehension or word reading skills does not compensate for having a deficit in the other skill.

On the other hand, Perfetti's (1977) additive model ($R = D + C + X$) may better describe the relationship between the two variables in normal samples with children who have age-appropriate language comprehension and decoding skills. The present sample of primary school children has a normal range of oral comprehension and word reading skills and therefore an additive model may better predict reading comprehension in this instance.

In both the *simple view* proposed by Hoover and Gough (1990) and the additive variant of this model proposed by Dreyer and Katz (1992), word reading skills are conceptualized as phonological recoding, measured by nonword or regular word reading. Perfetti (1985), on the other hand, conceptualizes decoding as "the transformation of a string of letters into a phonetic code" (p.90), and includes the reading of both regular and irregular words. Perfetti's model also allows for other skills not recruited by the reading or oral comprehension processes, although he argues that their influence is small relative to that of word reading skills and oral comprehension.

It is of note that the statistical analyses used to test additive versus multiplicative models are frequently not carried out in accordance with accepted statistical theory. In statistical theory on multiple regression and correlational analysis, a multiplicative formula, such as D x C, is viewed as an interaction (see Cohen & Cohen, 1983, p301). Cohen and Cohen (1983) point out that two variables are said to "interact" when they account for variance over and above the additive combination of their separate effects. The linear expression of the multiplicative version of the *simple view* is therefore R = D + C + (D x C), since the intersection (D x C) is undefined without the prior entry of the individual terms of D + C. The multiplicative model cannot therefore be tested without first entering the additive combination of those variables.

This statistical premise is often not adhered to (e.g. see Dreyer & Katz, 1992; Hoover & Gough, 1990; Joshi & Aaron, 2000), which can compromise the findings. For example, Joshi and Aaron (2000) calculated the correlation co-efficient between reading comprehension and the product of decoding and oral comprehension, D x C. The correct statistical procedure is to calculate the partial correlation between reading comprehension and D x C after controlling for D and C. On the other hand, Dreyer and Katz (1992) and Hoover and Gough (1990) did calculate the amount of variance that D x C contributed to R beyond D + C. However, both sets of researchers also conducted further hierachical regression analyses in which D x C was entered prior to D + C, which, as discussed above, is statistically incorrect.

Although oral comprehension and phonological recoding skills may account for a considerable amount of the variance of performance in children's reading comprehension tasks, it may be possible to formulate a more sophisticated model that predicts children's reading comprehension after the acquisition of preliminary word reading skills. A more elaborate model may encompass the addition of factors other than 'D' or 'C' or alternatively 'D' and 'C' may be multifaceted.

For example, word reading skills may be better represented by a measure which incorporates orthographic processing skills in addition to phonological recoding skills. Research by Nation and Snowling (1998) with children who are poor comprehenders, suggests that non-lexical processes, operationalised as nonword reading, may not be as good a predictor of reading comprehension as lexical processes, measured by irregular word reading. This may be the case particularly when children are no longer in the initial stages of learning to read and have acquired adequate phonological recoding skills.

Another aspect of word reading that has been ignored in traditional models such as the *simple view* is reading speed. According to *verbal efficiency theory*, “the quality of a verbal processing outcome is relative to its cost to processing resources” (Perfetti, 1985 pp.102), meaning that less efficient verbal processing requires more attentional resources and places greater demands on WM. Thus, children who are slower, less fluent readers may have less WM resources available for comprehension.

The amount of prior exposure to print has been associated not only with a more extensive orthographic lexicon and better language skills (Cunningham & Stanovich, 1998; Cunningham, Stanovich, & West, 1994; Stanovich & Cunningham, 1992) but also with superior knowledge of typical narrative format (Cain, 1996). Although knowledge of narrative format may be important in comprehending orally presented, as well as written stories, familiarity with features in the text such as punctuation, titles and paragraphing are specific to written language. Exposure to print may therefore be an independent predictor of reading comprehension and may add to the predictive power of a model of reading comprehension beyond the contribution of either word reading skills or oral comprehension.

The claim that children's poor reading comprehension is linked to WM deficits is not unanimously supported. The main opposing theoretical position is that poor comprehension is associated with less developed language skills (Nation et al., 1999). It is certainly possible that language skills may be more crucial to reading comprehension than WM when the material to be comprehended can be reread as many times as is necessary to circumvent encoding problems and performance may be more dependent on semantic and syntactic processing.

It should be noted that in Hoover and Gough's original study (1990) which was designed to test the *simple view*, reading comprehension was assessed in the absence of the text. As such, in their study, the reading comprehension and oral comprehension measures had very similar demands. Both were measured using parallel tests from the Interactive Reading Assessment System (IRAS). Comprehension was assessed by asking children to recall as much information as they could from a narrative passage. Scores were allocated according to whether the story elements were remembered in the free recall or the cued recall condition, with more points being allocated for remembering in the free recall condition. Performance in both the oral and reading forms of the comprehension test was therefore heavily dependent on memory. In other types of reading comprehension tests the text is available to participants at all times and hence, performance is less reliant on memory in general and may be more dependent on language skills.

Another factor that has been relatively ignored in research on reading comprehension is LTM or the ability to retrieve verbal material following a delay. Verbal memory retrieval may be an important predictor of reading comprehension since comprehension is a constructive process in which information in the text is integrated with items retrieved from LTM. The ability to retain verbal information after a delay, with repetition of the information at the encoding stage, may contribute to reading comprehension when the text is available to participants to reread. The comprehension of orally presented information may be more dependent on encoding processes (STM) since in this mode of presentation, there is no opportunity to go back over the information. Verbal learning and retrieval may therefore add to the prediction of reading comprehension beyond the contribution of oral comprehension or WM.

In summary, there is reason to doubt that traditional developmental models, such as the *simple view* will be able to adequately account for reading comprehension in children once they are past the preliminary stages of learning to identify words. When reading comprehension is measured with the text available, as is usually the case, performance may be more dependent on language skills and less dependent on memory. The addition of other variables such as orthographic skills, reading speed and exposure to print may add to the prediction of reading comprehension and may make phonological recoding skills a redundant predictor.

The theoretical and empirical evidence for the selection of variables to include in a model of reading comprehension will now be examined. These variables can be categorized into three main types: 1) word reading 2) language skills and 3) memory. It is acknowledged that some of the variables subsumed by the term “word reading” are not direct measures of “word reading”. The term is used to distinguish them from reading comprehension. Alternatives such as “reading” or “reading skills” would lead to confusion since “reading” or “reading skills” is used in the literature to refer to reading comprehension.

2.2 Word Reading

Word reading is often termed “decoding”. In *the simple view,* however, the term “decoding” refers only to nonword reading accomplished through phonological recoding (Gough & Tunmer, 1986). According to *the simple view,* reading comprehension can be predicted from the product of oral comprehension and phonological recoding skills. The relationship between reading comprehension and word reading may indeed be more complex.

While beginner readers may rely primarily on a phonological recoding strategy, more competent readers may be more dependent on orthographic processing. Section 2.2.1 focuses on the selection of the constituent processes to represent word reading accuracy in the model aimed at children in the middle primary school years. Exposure to print and reading experience may be crucial in helping to build up word reading skills. However, exposure to print may enhance reading comprehension in ways other than by improving word reading. These issues will be discussed in Section 2.2.2. Reading speed or the rate at which words are read may also impact on reading comprehension through its association with WM efficiency (Perfetti, 1985). In Section 2.2.3, there will be a review of the evidence on whether reading speed contributes to reading comprehension beyond the contribution of word reading accuracy. Finally, in Section 2.2.4, there will be a summary of the implications of the findings of previous research on the relationship between word reading and reading comprehension for the current study.

2.2.1 Word Reading Accuracy

It is frequently assumed that difficulties in reading comprehension in children are associated with problems in word reading. The emphasis on the teaching of literacy often focuses on the acquisition of adequate word reading skills, and comprehension is frequently treated as the natural corollary of competent reading. It is true that poor comprehension can be the result of inaccurate or slow and non-fluent word reading. There is general agreement that adequate word reading skills are an essential component of reading comprehension, with reading comprehension skills typically being strongly correlated with word reading skills. Correlations between the two have been found to be between .60 and .80 (Yuill & Oakhill, 1991).

Poor word reading skills are associated with deficits on measures of verbal STM and verbal WM (Hulme & Snowling, 1992) and also with inferior language skills (Garton & Pratt, 1998). Many of the studies designed to investigate the aetiology of poor reading comprehension in children control for word reading skills (e.g., Nation et al.,1999; Oakhill, Cain & Yuill, 1998). That is, groups of adequate and poor comprehenders are matched on their word reading skills in order to exclude the influence of this variable. However, when the aim is to formulate a developmental model of reading comprehension, word reading skills are an important component.

Word reading involves both lexical and nonlexical processes (Coltheart, Curtis, Atkins, & Haller, 1993). Models such as *the simple view* only include a nonlexical component, that is, phonological recoding skills. The results of work by Nation and Snowling (1998) show that poor comprehenders can have adequate phonological recoding skills but still have problems reading words with irregular spelling patterns and low frequency words. This suggests that lexical (or orthographic) processes may be a valuable addition to a developmental model of reading comprehension. This may particularly be the case for children who have passed the initial stages of learning to identify words and have well developed phonological recoding skills.

2.2.1.1 Lexical Versus Non-lexical Processes

According to an influential theory, the Dual Route theory, word reading skills can be broken down into two components: the nonlexical or phonological recoding route, which is used to read unfamiliar regular words, and the lexical route, which is used to read familiar words and irregular words (Coltheart et al., 1993).

According to the Dual Route model, unfamiliar regular words can be read by phonological recoding, which involves using knowledge of the rules of letter-sound correspondences to convert the graphemic representation of the word into a phonological representation. This representation is then used to gain access to the meaning of the word as represented in the appropriate entry in the mental lexicon. This sequence of processes is referred to as the nonlexical or the phonological recoding route. Phonological recoding skills are best measured by nonword (pseudoword) reading since novel nonwords can only be read via the nonlexical route (Hoover & Tunmer, 1993).

On the other hand, familiar regular words and irregular words are read via the lexical route which involves word-specific orthographic mechanisms. That is, the process allows direct access of the lexical representation from the orthographic representation. Orthographic processing skills can be measured by irregular word reading since irregular words cannot be read entirely by using a phonological recoding strategy.

There is some evidence to suggest that poor comprehenders can have adequate phonological recoding skills but still have difficulties with irregular word reading. In a study with 16 normal readers and 16 poor comprehenders, Nation and Snowling

(1998) found that the poor comprehenders were worse at reading words with irregular spelling patterns and low frequency words than normal readers. The two groups were matched on phonological recoding ability (nonword reading), chronological age and nonverbal ability. Interestingly, even though the groups were matched on phonological recoding ability, their reading accuracy on the Neale, which involves the reading of text containing regular and irregular words, was 10 months lower than the normal readers. This difference approached statistical significance. Poor comprehenders were found to be worse on a test of receptive and expressive vocabulary, as well as higher level aspects of word knowledge, such as multiple meanings or figurative usage. Nation and Snowling concluded that poor comprehenders have difficulty reading irregular words because such words are normally read with support from semantics and that they have weak semantic processing ability. Nation and Snowling also concluded that semantic skills influence text reading, which explains why poor comprehenders performed less well on the Neale.

Irregular word reading may incorporate variance due to both phonological recoding skills and language ability. In support of this contention, Tunmer and Chapman (1998) demonstrated in a large sample of over 300 children in grades 2 and 3, that children's irregular word reading is dependent on both the ability to convert letters to sounds (phonological recoding) and the ability to instantiate the meaning of the word from the context in which it occurs. For example, although children often read the word stomach as stow-match when it was presented in isolation, when the word was presented in a sentence such as, “the football hit him in the stomach” most children immediately identified the word correctly. The irregular words selected could not be read using context alone but required some phonological analysis to read them correctly. It is to be expected therefore that phonological recoding and irregular word reading will be highly correlated in normal samples.

These findings are compatible with Cunningham and Stanovich’s (1990; 1991; 1998) research in normal populations that links the development of orthographic processing skills with general verbal ability and exposure to print. This body of research will be discussed in more detail in Section 2.2.2 on the relationship between reading comprehension and exposure to print.

Irregular word reading may be a particularly powerful predictor of reading comprehension if it is associated with both phonological recoding and language skills. Models of reading comprehension may therefore have more predictive power if “decoding” is measured as irregular word reading rather than nonword reading (phonological recoding).

Children cannot learn to read without first being exposed to print. Reading experience and exposure to print may be an important tool in the development of reading comprehension skills. Cunningham and Stanovich’s research (Cunningham &

Stanovich 1998; Cunningham et al., 1994) suggests that exposure to print is instrumental in the build up of the orthographic lexicon and in enhancing verbal skills. Exposure to print may also be a unique predictor of reading comprehension and may add to the predictive power of a model.

2.2.2 Reading Experience And Exposure To Print

There is a considerable amount of evidence that better word reading skills are associated with more frequent exposure to print and reading experience. Nagy and Anderson (1984) calculated that while voracious readers might read 10,000,000 or even 50,000,000 words a year in in-school reading, children who are less motivated might read only 100,000. They conclude that there are enormous individual differences in the volume of language children experience and in their opportunities to learn new words. Fielding, Wilson and Anderson (1986) found that there are large differences in the amount that children read outside of the classroom and that this is associated with their word reading skills.

Stanovich (1986) suggests that the relationship between word reading skills and exposure to print is bi-directional. That is, not only does increased exposure to print facilitate better word reading skills but, conversely, children with better word reading skills are motivated to read more, so that they further improve their already competent skills. On the other hand, children with poor word reading skills read much less and their inferior skills lag further and further behind their peers who have competent word reading skills.

Cunningham and Stanovich and their research group have conducted many studies investigating the relationship between exposure to print, word reading skills and cognitive growth, particularly in language and declarative knowledge (Cipielewski & Stanovich, 1992; Cunningham & Stanovich, 1991, 1997; Cunningham et al., 1994). They developed and validated measures of individual differences in print exposure: the author recognition test (ART), the magazine recognition test (MRT), and the title recognition test (the TRT). While the ART and MRT were developed for use with adults, the TRT can be used with young primary school students and Cunningham and Stanovich (1998) contend that it can be viewed as a measure of the general literacy environment in the home or, alternatively as a proxy measure of the child's reading activity. The measure was designed to prevent the problem of socially desirable responding and contamination by inaccurate estimates of the time or frequency of reading activities. Children are required to recognize the titles of real book titles, selected from amongst common, age-appropriate books, that are scattered amongst fake book titles (Cunningham & Stanovich, 1991).

Research by Cunningham and Stanovich (1990; 1998) and Stanovich and West (1989) suggests that the development of orthographic processing skills may not be entirely dependent on phonological processing ability and may be influenced by the amount of exposure to print.

Stanovich and West (1989) found that individual differences in the amount of exposure to print were associated with the variance in orthographic processing after phonological processing ability had been partialled out. Cunningham and Stanovich (1998) replicated this finding in a study with 26 grade 1 children. In this study there were three phonological processing tasks, which included phoneme deletion and transposition, and two orthographic processing tasks, which included a spelling task and a letter-string choice task in which children had to choose strings which looked more like words. The researchers acknowledged that the orthographic processing tasks also recruited phonological processing skills. The TRT was used as a measure of exposure to print. An hierarchical regression analysis showed that exposure to print accounted for significant variance in orthographic processing variance once differences in phonological processing had been partialled out. Although the TRT correlated with general word reading and orthographic processing measures, it was not significantly correlated with the phonological processing tasks.

Cunningham and Stanovich (1998) point out that other studies have shown moderate correlations between exposure to print and phonological processing. They contend however that print exposure is related to precise representations in the lexicon (orthographic processing) but only indirectly to phonological knowledge.

Cunningham and Stanovich believe that even in early development, exposure to print is more strongly related to orthographic rather than phonological processing and maintain that exposure to print plays a large part in the build up of the orthographic lexicon.

Research by Cunningham and Stanovich's research group suggests that exposure to print impacts on reading comprehension ability independent of its effect on word reading skills. A study with 98 children by Cipielewski and Stanovich (1992) showed that exposure to print predicted growth in reading comprehension over a 2-year period from grades 3 to 5. The TRT was found to predict 11% unique variance in reading comprehension scores in grade 3 and 7.4% unique variance in grade 5 even after word reading skills had been partialled out of the analyses. It seems that exposure to print facilitates reading comprehension in ways other than by simply enhancing orthographic processing skills.

Exposure to print may make a contribution to reading comprehension in several other ways. First, there is substantial evidence that exposure to print may aid comprehension by helping to build up language skills and declarative knowledge (Cunningham et al., 1994; Stanovich & Cunningham, 1993; Stanovich, West, Cunningham, Cipielewski, et al., 1996). Secondly, it may make an independent contribution by increasing familiarity with narrative structure.

Cunningham and Stanovich have demonstrated a significant relationship between reading experience and vocabulary knowledge in several studies (Cunningham & Stanovich, 1991; Echols, West, Stanovich, & Zehr, 1996; Stanovich & Cunningham, 1992; Stanovich et al., 1996). Cunningham and Stanovich (1991) found that print exposure accounted for a significant portion of the variance in vocabulary beyond that attributable to non-verbal intelligence and phonological recoding ability. The results suggest that the amount of prior print exposure is a substantial contributor to the growth of verbal cognitive structures. Stanovich believes that print is a more significant contributor to vocabulary development than speech because print is much more lexically rich since it contains a greater diversity of words. In those with poor reading comprehension, Stanovich's research shows that exposure to print facilitates vocabulary development and also the development of declarative knowledge bases, which can lead to improved comprehension. This suggests that poor reading comprehension may be able to be remediated via increased print exposure (Stanovich et al., 1996).

Exposure to print may make an independent contribution to reading comprehension by increasing familiarity with narrative structure which has been found to facilitate reading comprehension (Cain, 1996). Children must be exposed to print in order to become familiar with typical narrative formats. Many children's stories have characteristic beginnings and endings such as, "Once upon a time…" and "and they all lived happily every after". The main protagonist is usually introduced early in the story, “Once upon a time on a small island there lived a little old woman….”. That is, there are recognised literary conventions in children’s story telling which provide a framework for the narrative. The stories also tend to contain a certain type of grammar which children themselves identify as being more “story like” (Bruce, 1980). Children also expect that a story will consist of a sequence of causally related events.

Cain (1996) found that children of between 6 and 8 years with poor reading comprehension had poor metacognitive knowledge about stories. They were less aware of the purpose of specific textual features such as titles, beginnings and endings. They were also less aware of the fictional nature of stories and, for example, were more likely to believe that little Red Riding Hood was a real person or that the things in the story really happened. The finding that story knowledge is strongly related to reading comprehension supports Stanovich’s contention that reading experience has a large impact on comprehension ability. It also implies that exposure to print may be a unique predictor of reading comprehension, contributing to comprehension beyond its association with word reading.

Although exposure to print would be expected to contribute to oral comprehension through its facilitation of language skills, exposure to print may make a unique contribution to reading comprehension even when written and orally presented material have similar content, and performance is not dependent on knowledge of narrative format. Exposure to print increases familiarity with devices that are specific to written language, such as punctuation or spelling, which are used to convey meaning (Rubin, 1980). The inclusion of exposure to print may therefore increase the predictive power of models of reading comprehension even when oral comprehension is also included as a predictor variable.

2.2.3 Reading Speed

Reading speed may be an important predictor of reading comprehension since it has been linked to WM efficiency (Perfetti, 1985). Traditional models of reading comprehension such as the *simple view* fail to allow for the effects of reading speed. Many studies on children's reading comprehension do not include a measure of reading speed (e.g., Cain, Oakhill, & Bryant, 2000; Nation et al., 1999; Oakhill & Cain, 2000), thus failing to consider the independent effect of speed as opposed to accuracy. When reading is faster and more automatic, children may use less resources on the word reading component of the task and have more resources to devote to comprehension. Models of reading comprehension may therefore benefit from the addition of reading speed as a predictor variable.

There has been no conclusive demonstration that reading speed is an independent predictor of reading comprehension after controlling for word reading skills. Perfetti and Hogaboam (1975) found that although poor comprehenders, who were in third and fifth grade, could identify words correctly, they read the words significantly more slowly than skilled comprehenders. For common high frequency words the differences were slight but still significant and the difference in speed increased as the words became less common. Less skilled comprehenders were also slower than more skilled comprehenders at naming nonwords that conform to English spelling rules. The slower word naming of the poor comprehenders could not be explained by slower articulation rates since they were able to name non-verbal stimuli, such as colors and pictures, just as quickly as those with adequate comprehension skills. Perfetti (1977) concluded that the slower latencies are indicative of longer processing times for orthographic-phonetic analysis in poor comprehenders. It should be noted however that Perfetti did not control for levels of word reading accuracy in these studies and although the children who read the words more slowly were able to read those words accurately, they may have been generally poorer readers.

Processing speed, that is, the speed at which an individual can absorb and manipulate information, has been shown to have a very significant impact on WM performance in children (Case, Kurland, & Goldberg, 1982; Fry & Hale, 1996; Towse, Hitch, & Hutton, 1998). Case and his colleagues demonstrated that there is a positive linear relationship between performance in a counting span task and increases in the speed of counting in primary school children. The counting span task was developed to measure *M space,* which is defined as the amount of resources an individual has for executing intellectual operations. The aim of the task is to count the number of dots on each of a series of cards and then to remember the number of dots on each. When adults and 6-year-old children were equated on speed of counting by getting the adults to count in an unfamiliar language, their counting spans did not differ significantly; that is, more items are recalled in the counting span task when counting is carried out more rapidly. Case et al., (1982) argue that this indicates that development increases in processing resources (or WM) do not result from increases in total capacity but rather with development, basic operations become faster and more efficient. As a result, less processing space is required, and more space becomes available for storage. From this perspective processing speed is not generalized but is task dependent. The implication is therefore that reading comprehension is dependent on reading speed.

Perfetti's (1985; 1988) finding that poor comprehenders are frequently slow and inaccurate readers has also been explained by the assumption of a limited capacity WM system such as is advocated in verbal efficiency or bottle-neck theories, in which good reading comprehension is assumed to depend on the efficiency of local processes, such as lexical access. Conversely, less efficient processing requires more attentional resources and places greater demand on WM, leaving less resources available for comprehension. Kintsch and van Dijk (1978) point out that readers who have not yet attained automaticity in their word reading processes may have to concentrate their resources at the micro level of understanding and may have insufficient resources to construct a macro-level representation. Alternatively, the relationship between reading comprehension and WM can be viewed in terms of the 'trace decay model". If children identify words less rapidly, the representations of words may be lost from WM before children can generate the meaning for a phrase or sentence (Hitch & Towse, 1995).

Researchers who subscribe to the hypothesis that poor comprehension is the result of less automatised word reading assume that the reader can reduce the resource demands of some processes through learning and practice. That is, individual differences in reading comprehension are viewed as being the result of limitations in functional rather than structural WM capacity. Individuals can have the same structural STM capacity but different functional memory capacity. From this perspective, functional memory capacity is believed to be dependent on processing efficiency. This conceptualization of WM is referred to as the processing efficiency hypothesis.

On the other hand, several studies which have excluded children with poor reading accuracy have failed to replicate Perfetti's (1985) finding that poor comprehenders read more slowly than adequate comprehenders (Stothard & Hulme, 1996; Yuill & Oakhill, 1991). Yuill and Oakhill (1991) compared the reading speed of 28 children divided into equal groups of good and poor comprehenders. They found no difference in the speed with which the children, who were matched on vocabulary knowledge and word reading accuracy, decoded either high or low frequency single words. Yuill and Oakhill (1991) concluded that single word reading may not predict individual differences in reading comprehension, implying that text reading speed may be a better predictor of reading comprehension.

However, Stothard and Hulme (1996) were unable to find any differences between poor comprehenders and chronological age controls in text reading speed, although speed was measured on the Neale in which reading accuracy, speed and comprehension are calculated on the same test. It may be that reading speed is not critical to reading comprehension in competent readers, although the use of a test in which reading accuracy and reading comprehension are measured on the same test is problematic. Some of the children (who were between 7 to 8-years-old) may have focused their efforts on reading the passages aloud correctly, while others may have focused on comprehending the text. Furthermore, if a relationship between reading comprehension and reading speed was found, it would be impossible to know whether comprehension was determining reading speed, that is, children may adjust their reading speed to facilitate comprehension of the text, or whether reading speed was determining comprehension.

It must be concluded that there is little support for the hypothesis that poor reading comprehension is associated with slower reading, after accounting for the contribution of word reading skills, in poor comprehenders. This does not preclude the possibility that reading speed is an independent predictor of reading comprehension in normal populations, particularly since reading speed can be seen as an index of processing speed; that is, children may read at a speed at which they are able to comprehend. Hence, reading speed may be a useful predictor of reading comprehension in normal populations and may add to the prediction of reading comprehension beyond the contribution of word reading accuracy. In the current study it will be investigated whether the addition of reading speed strengthens the predictive power of a model of children's reading comprehension. Reading comprehension and reading speed will be measured on separate tests.

2.2.4 Summary:Word Reading

Reading comprehension is dependent on adequate word reading skills. Word reading can be broken down into three components: phonological recoding (measured by nonword reading), orthographic processing (measured by irregular word reading) and reading speed. Of these components, the evidence suggests that orthographic processing may be the strongest predictor of reading comprehension since it may capture variance in both phonological recoding ability and language skills. Exposure to print may facilitate orthographic processing and language skills but may also be a unique predictor of reading comprehension since it increases familiarity with narrative format which is crucial to the comprehension of children's stories It is unclear whether reading speed will add to the prediction of reading comprehension beyond the contribution of word reading accuracy. The balance of the evidence suggests that it may not, although much of this research has been conducted with groups of poor comprehenders.

In the current study it will be investigated whether orthographic processing (irregular word reading), phonological recoding (nonword reading), exposure to print and reading speed make independent contributions to reading comprehension. The variables that make independent contributions will be included in a model of children's reading comprehension developed specifically for children who have passed the initial stages of learning to read. The predictive power of this model will be compared with that of a model comprising phonological recoding skills and oral comprehension.

2.3 Language Skills

As discussed in Section 2.1.1.1, children with more developed language skills have a more extensive knowledge of word meanings and more developed semantic networks and may be better able to use contextual cues to read irregular words. Children's knowledge of irregular words may therefore be a reflection of their general language ability. Environmental influences, such as exposure to print, may help build language skills and other skills recruited in reading comprehension, including the reading of irregular words (Cain, 1996; Cunningham & Stanovich, 1991; Echols et al., 1996; Stanovich et al., 1996).

Apart from factors related to word reading, many researchers believe that language skills make the most significant contribution to children's reading comprehension. Language disorders have been found to be powerful predictors of later problems in both reading and listening comprehension and there is a substantial amount of evidence in studies with poor comprehenders to suggest that poorer comprehension skills can be related to lower language skills (Nation & Snowling, 1998; Rosenshine, 1980; Stothard & Hulme, 1996; Tramontana, Hooper, & Selzer, 1988). In children who have no identified language deficits, there is much evidence of a linear relationship between reading comprehension and language skills (Baddeley, Logie, & Nimmo Smith, 1985; Gottardo, Stanovich, & Siegel, 1996; McKeown, Beck, Omanson, & Perfetti, 1983; Roth & Perfetti, 1980; Stanovich et al., 1996).

This section focuses on the relationship between reading comprehension and language skills. Three aspects of language skills will be considered: 1) the comprehension of oral language (oral comprehension) 2) semantic skills and 3) grammatical and syntactic skills. In the following section, the rationale for the inclusion of oral comprehension as a predictor in models of reading comprehension will be discussed. This will be followed by a section on the relationship between reading comprehension and both semantic and grammatical and syntactic skills. It will be argued that language skills, particularly semantic knowledge facilitates irregular word reading. To conclude this section, there will be a summary of the implications of the findings of previous research on the relationship between language skills and reading comprehension.

2.3.1 Oral Comprehension

From the developmental perspective, reading comprehension can be viewed as a derived skill that is grafted onto oral language comprehension (Gough, Hoover, & Peterson, 1996; Rubin, 1980; Tunmer & Hoover, 1992). According to this view, young children learn to map the printed text onto their existing language. Certainly, it has been found that children must reach a threshold level of competence in the language being read before they can make any progress in reading (Tunmer & Hoover, 1992). From this theoretical perspective, oral and written language comprehension involve essentially the same processes in which reading entails decoding the orthographic symbols to a phonemic representation and then comprehending it in the same way as if it were speech.

This approach is supported by the fact that generally, children who are poor at reading comprehension also tend to perform poorly in tests of oral or listening comprehension (Cornoldi et al., 1996; Gernsbacher, Varner, & Faust, 1990; Nation & Snowling, 1997; Stothard & Hulme, 1992). In a large study with 184 child participants aged between 7 and 9 years, Nation and Snowling (1997) calculated the partial correlation between reading and listening comprehension to be .63, after controlling for chronological age. This correlation increases with age as children develop their reading skills (Cornoldi et al., 1996). Gernsbacher et al., (1990) found that in a large sample of young adults, the correlation between the comprehension of written and spoken stories was .92.

However, reading and oral comprehension skills do not always overlap. In a longitudinal follow-up of 12 single case studies, Cornoldi et al., (1996) found that only 5 of the 12 participants had both poor reading comprehension and poor oral comprehension of a text presented on television. According to *the simple view*, adequate oral comprehension skills are a prerequisite of adequate reading comprehension skills. However, Cornoldi et al., (1996) found no unique pattern of difficulties in their comparison of 12 individuals and concluded that reading comprehension is not necessarily due to problems in listening (oral) comprehension.

There may be differences between the types of skills required in reading comprehension as opposed to oral comprehension, which do not rely on word reading skills alone (Rubin, 1980). Both reading and oral comprehension involve some common cognitive processes such as word recognition, syntactic and semantic processing of a sentence and the integration of information. Rubin (1980) however contends that there are a great many distinctions between reading and oral language comprehension and rejects the traditional equation defining reading comprehension as a combination of oral comprehension and word reading skills. He presents a taxonomy of differences between the two, dividing these differences into two large subcategories: those relating to the communicative medium (modality) and those relating to the message (content).

Rubin (1980) points out how the modality of presentation (that is, either written or spoken) affects comprehension. He argues that the comprehension of spoken language is made easier for children by the use of stress intonation and other prosodic features. For example, temporal characteristics of speech, such as changes in speed or pauses, provide clues for combining the words into meaningful chunks. Stress can be particularly useful as it facilitates the detection of syntactic and discourse structure; for example, stress on pronouns can help disambiguate their referent (in “Jack hit Paul and *Jill* hit him” the referent is Paul, while in “Jack hit Paul and Jill hit *him”* the referent is Jack). On the other hand, punctuation in written language can be seen as a partial analogue of the prosodic features of spoken language. Although punctuation is limited and does not reflect all the nuances possible with speech, it can, for example, indicate emphasis (!), or uncertainty (?), pauses (,) and related statements (;). The demarcation of text into paragraphs can also act as an organizational aid and devices such as underlining and italicizing can be used to add emphasis or contrast words and phrases. The spelling of words can also act as a guide to meaning since spelling can be used to establish the meaning of ambiguous words (e.g., sale and sail) (Gough et al., 1996).

Another important difference that Rubin (1980) notes between the modalities of written and oral language is the permanence of written language allowing readers to look back over previously read passages and to reread ambiguous or difficult sentences. In contrast to reading comprehension in which the readers can tailor their reading speed to their speed of comprehension, in oral comprehension tasks the rate of presentation is variable and not self-regulated. Memory and processing speed may therefore be more predictive of oral rather than reading comprehension when reading comprehension is measured with the text available as normally occurs when children read.

Rubin (1980) categorises other differences between reading and oral comprehension in terms of message-related dimensions. Even though children may hear oral stories from their parents, their typical oral language experiences are conversations. The structure of oral language used in conversation is different to that of written stories. Conversational structure tends to be characterized by utterances which are very sensitive to the context in which they occur because of the interaction between the speaker and the listener. Particular sequences of conversation have been identified such as [question]-[answer]. Sequences tend to be short and misunderstandings can be resolved quickly because of the interactive nature of the medium. The syntax of oral language can be ungrammatical and the words children hear tend to be familiar to them.

The language structure of stories, on the other hand, differs enormously from that of conversation and Rubin (1980) argues that children must learn a new set of language structures and procedures to comprehend stories. Written stories generally comprise more sophisticated language, containing words, syntax and grammatical structures that are not generally used in everyday conversation. Children learn to make use of the semantic and syntactic structure to extract meaning and better comprehenders seem to be more adept at doing this. Knowledge of narrative structure, that is, the typical layout or ordering of stories, may also be an aid to comprehension (Cain, 1996; Stanovich & Cunningham, 1993). As has been argued by Stanovich et al., (1996) reading experience may be vital to building up the skills required for reading comprehension.

Another difference between the written and oral mediums is that the topics of written as opposed to spoken language vary, with children in general talking about familiar people, everyday objects and situations; whereas stories are likely to contain information about unfamiliar people, objects and situations. Rubin (1980) found that an important component of comprehending a story is in understanding the characters goals and interpreting their actions in light of these goals. This requires children to be able to assume the characters' point of view which is difficult for children when they are not in that situation themselves and requires a level of cognitive sophistication not usually required in speech about familiar themes.

Thus, although there is much overlap between the skills required for reading and oral comprehension, there are also important differences between the two. Even when the content of orally presented and written narratives are of similar linguistic complexity and on similar topics, the modality of presentation may still influence the type of skills that have the most impact on performance. That is, oral comprehension skills may be more reliant on memory and processing speed since, unlike reading comprehension, it is not possible to go back to previously presented information and the rate of presentation is not self-regulated. On the other hand, reading comprehension with the text available, may be more reliant on language skills, prior knowledge and retrieving previously learned information from LTM.

The implication of this discussion on the differences between reading and oral comprehension is that it may be difficult to draw up a comprehensive model of reading comprehension in children because of the number and complexity of the skills involved and because the balance of these skills may change over time. Although there are many similarities between reading and oral comprehension and there may be a high correlation between the two, making oral comprehension a strong predictor of reading comprehension, there are also important differences between them. While oral comprehension is a general reflection of language skills, specific aspects of language, namely semantic and grammatical skills, may be particularly crucial to reading comprehension.

2.3.2 Semantic and Grammatical Skills

It has been estimated that approximately 10% of children in their middle school years have poor reading comprehension although their word reading skills are normal (Nation, et al., 1999). Nation and her colleagues believe that poor comprehenders with adequate word reading skills have an underlying language impairment, particularly delays in semantic and syntactic skills (Nation et al., 1999).

They suggest that children’s comprehension deficits are strongly associated with delayed development of the semantic memory system. In a study investigating the effects of reading words in isolation versus reading the same words with contextual support, Nation and Snowling (1999) found that poorer comprehenders demonstrated less contextual facilitation than normal readers. Poor comprehenders were also found to have a less developed vocabulary than age-matched controls of equivalent decoding ability. Nation and Snowling (1999) argued that poor comprehenders have a less developed semantic memory system and may not yet have developed a categorically structured organisation of semantic memory. This impairment in semantic processing skills in poor comprehenders may be associated with their reduced ability to read irregular words since reduced sensitivity to contextual information may impact on their ability to read (irregular) words that are typically read with support from semantics. Consequently, Nation and Snowling (1998) predict that the word knowledge of poor comprehenders will increasingly lag behind that of children with normal semantic processing skills.

Language ability has also been found to be a significant predictor of reading comprehension in populations of children who have no reported comprehension deficits. Storch and Whitehurst (2002) formulated a model of reading comprehension using structural equal modeling (SEM) in a large longitudinal study, with a sample of 626 children from preschool to grade 4. They found that reading comprehension was determined by multiple factors including current language ability (in addition to prior and current word reading skills). Storch and Whitehurst found that after children have acquired some word reading skills, language skills have a direct impact on the comprehension of text by grades 3 and 4.

In fact, a recent longitudinal study by Roth et al., (2002) with 39 children from kindergarten to grade 2, suggests that language (semantic skills) may be a stronger predictor of reading comprehension than word reading ability by grade 2. Roth and her colleagues measured three domains of oral language including structural language, which included measures of semantic and syntactic skills. As in Storch and Whitehurst's (2002) study, one of the semantic measures was the PPVT. The findings of Roth and her colleagues may not be inconsistent with those of Storch and Whitehurst, who found that oral language skills were a unique predictor of reading comprehension in grades 3 and 4 but not grades 1 and 2. Storch and Whitehurst's findings may have reflected the nature of their sample, which comprised children from low income families, who were performing below the national average on word reading and vocabulary.

In addition to word-level semantic deficits, poor comprehenders have been found to have impaired grammatical skills relative to adequate comprehenders on both tests assessing grammatical awareness and tests of receptive grammar (Nation & Snowling, 2000; Stothard & Hulme, 1996). Nation and Snowling (2000) assessed syntactic awareness skills in children with good and poor reading comprehension who were matched for age, decoding skill and non-verbal ability using a word order correction paradigm. Poor comprehenders performed less well than normal readers. Syntactic awareness is a metalinguistic ability which is operationalized as the ability of children on demand to focus attention on the grammatical structure of a sentence (Bowey, 1994). Even though children may be unable to articulate a relevant rule, they may still be aware of the systematicities in a language.

Poor comprehenders have also been found to perform significantly worse than age-matched children who had normal comprehension skills on Bishop's (1983) Test for the Reception of Grammar (TROG) (Stothard & Hulme, 1996). The TROG measures understanding of grammatical concepts such as masculine and feminine personal pronouns, comparatives (e.g., "the knife is longer than the pencil") and neither X nor Y (e.g., "neither the dog nor the ball is brown"). The children with poor reading comprehension were found to perform at a similar level to younger children with whom they were matched for comprehension level. That is, the children's receptive grammatical skills were consistent with their level of comprehension, thus implying that grammatical deficits are associated with comprehension problems but do not play a causal role.

There are also several studies demonstrating linear relationships between reading comprehension and receptive vocabulary (Baddeley et al., 1985; McKeown et al., 1983; Stanovich et al., 1996) and studies demonstrating linear relationships between reading comprehension and grammatical skills in normal samples (Gottardo et al., 1996; Roth & Perfetti, 1980).

While the link between reading comprehension and receptive vocabulary has been established, the association between reading comprehension and grammatical skills is more controversial and some researchers believe that the strong relationship between the two is underpinned by verbal WM (Carpenter, Miyake, & Just, 1994; Gottardo et al., 1996; Martin & Romani, 1994). For example, individuals with low WM capacity have been found to have more problems understanding syntactically complex sentences (Carpenter et al., 1994).

Gottardo et al., (1996) investigated the relationship between phonological sensitivity, syntactic skills and verbal WM in the reading performance of grade three children. They found that syntactic skills failed to account for significant unique variance in reading comprehension in a group of 112 eight year-olds once a verbal WM and a phonological sensitivity task were entered into the regression equation. Of the three variables, the WM measure was the strongest predictor of reading comprehension, accounting for 12.5% of the variance.

Caplan and Waters (1999) point out however that there is a difference between syntactic complexity and the size of the memory load. They maintain that the load imposed on WM is a function of the number of propositions in the sentence (units of meaning) rather than of syntactic complexity. For example, the sentence, “It was the postman who delivered the letters” contains less propositions than the sentence, “The postman who delivered the letters was bitten by a dog”. The researchers found that participants with low verbal WM did not differ from those with high verbal WM in interpreting syntactically complex garden path sentences. However, those with low verbal WM performed more poorly on sentences with a greater number of propositions.

It is possible that studies showing a significant relationship between verbal WM and syntactic processing ability in children have confounded syntactic complexity with the number of propositions in a sentence. Gottardo et al., (1996) did try to eliminate this potential confound by allowing one repetition of the sentence in their syntactic judgement task and up to three repetitions in their syntactic correction task. They do not mention, however, whether they controlled for the number of propositions in the sentence.

Receptive measures of grammatical skills place less demands on WM than grammatical awareness tasks such as syntactic correction tasks. Syntactic correction tasks require concurrent processing and storage (that is, the sentence has to be simultaneously remembered and manipulated). On the other hand, in receptive tests of grammar, such as the TROG, although sentences must be remembered, they do not have to be manipulated in any way. Also, in the TROG, the sentence can be repeated as many times as is necessary to facilitate recall which helps circumvent problems with encoding. The use of receptive measures such as the TROG may therefore help disambiguate the results of findings suggesting an association between reading comprehension and grammatical skills.

2.3.3 Summary: Language Skills

Although there is substantial evidence for a strong linear relationship between reading comprehension and semantic skills, the evidence for a relationship between reading comprehension and grammatical skills is difficult to interpret. There is a strong association between grammatical skills and verbal WM, and verbal WM may underpin the relationship between reading comprehension and grammatical skills.

Both semantic and grammatical skills may contribute to reading comprehension but it is not clear whether these skills will add to the prediction of reading comprehension over and above the contribution of oral comprehension. Although, with the exception of word reading skills, reading and oral comprehension may draw on the same skills, the impact of these skills may differ according to the modality of presentation. Semantic and grammatical skills may be particularly powerful predictors of reading comprehension when encoding difficulties can be circumvented by re-reading the text and performance is more dependent on interpretation rather than memory of the text.

In the current study it will be investigated whether semantic and grammatical skills make an independent contribution to reading comprehension, measured with the text available, beyond that attributable to the comprehension of oral language. The test of semantic skills will be a measure of receptive vocabulary and grammatical skills will be assessed using a receptive measure of grammatical knowledge. There is some evidence that language skills may be strongly correlated with some of the word reading variables, that is, orthographic processing (irregular word reading) and exposure to print. Hence, although semantic and grammatical skills may make an independent contribution to reading comprehension beyond oral comprehension, the inclusion of the word reading variables in a statistical analysis may considerably lessen the power of the language variables to predict reading comprehension. It is not clear therefore whether the language variables will make an independent contribution to reading comprehension and if they will add to the predictive power of a model.

2.4 Memory

Reading comprehension involves remembering and integrating large amounts of information. While researchers such as Nation (1999) and her colleagues are of the view that problems with reading comprehension reflect underlying language deficits, many researchers in both the child and adult literature contend that WM is crucial to reading comprehension and that poor comprehension is causally related to WM deficits (e.g., Conway & Engle, 1996; Daneman & Carpenter, 1980; De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Engle, Cantor, & Carullo, 1992; Just & Carpenter, 1992; Palladino, Cornoldi, De Beni, & Pazzaglia, 2001; Seigneuric et al., 2000; Yuill et al., 1989).

Some researchers conceptualise these deficits in terms of reduced capacity to support the concurrent storage and processing of information (Conway & Engle, 1996; Daneman & Carpenter, 1980; Just & Carpenter, 1992; Oakhill et al., 1998) while others see them in terms of problems with WM inhibition mechanisms (De Beni & Palladino, 2000; Palladino et al., 2001).

There is also good reason to suggest that other aspects of memory, such as long term retention and retrieval, may be important to reading comprehension, since comprehension involves remembering large amounts of information, which are beyond the storage capacity of STM. However, the relationship between reading comprehension and aspects of longer term retention and retrieval has been little studied (with the exception of the literature on the relationship between reading comprehension and expert knowledge). The bulk of the literature on reading comprehension and memory relates to WM in which WM is measured as immediate rather than delayed recall.

Prior to a review of the evidence suggesting that WM plays a causal role in children's comprehension deficits, it is important to consider how WM is conceptualized. What follows is a discussion on the two most prominent types of WM models in the reading comprehension literature: single resource models and multi-component models. This will be followed by a section on the measurement of WM in reading comprehension research. There will subsequently be a review of the literature on the relationship between reading comprehension and WM resources, and between reading comprehension and WM inhibition mechanisms. This will be followed by a section on methodological issues relating to the selection of appropriate WM tasks.

It has been noted that there has been little research on the relationship between reading comprehension and longer term retention and retrieval. Following the discussion on the relationship between reading comprehension and WM, there will be a review of the evidence that LTM also plays a role in reading comprehension.

2.4.1 Single Resource Models of WM

Working memory, a term coined by Baddeley and Hitch (1974), is conceptualized as an active system for temporarily storing and manipulating information needed in the execution of complex cognitive tasks. The system maintains information in an active state to support on-line processing (Banich, 1997) and has been described as the "desktop" of the brain (Logie, 1999, p174). It is assumed that WM is the tool that is used to build up a representation of the to-be-comprehended information.

Single resource models of WM such as those described by Case (1987) and Turner and Engle (1989) assume that WM tasks draw on a single pool of resources that is independent of modality (e.g., verbal or visuospatial or domain (e.g., receptive or expressive language). Individual differences in WM capacity are believed to result from biological factors and to be closely related to Spearman's "g" or general intellectual potential (Engle et al., 1992).

It is assumed that information becomes accessible in WM when it has been activated above some critical threshold. Working memory capacity is not conceptualised simply in terms of storage capacity but rather as the ability to sustain an active memory trace, regardless of attentional shifts or distraction (Kane, Conway, & Engle, 1999). Consequently, WM is not just a measure of STM storage capacity but the amount of activation available to support the processing and storage of information (Just & Carpenter, 1992).

The single resource model of WM seems to have largely fallen out of favour. Those who conceptualise WM in terms of amounts of activation do not necessarily endorse a single resource model of WM. Just and Carpenter (1992) who, like Engle and his colleagues, favour the activation model of WM, do not endorse a single resource theory of WM. Instead, they propose that WM can be broken down into different pools of resources. Just and Carpenter (1992) maintain that one pool of resources is specific to language comprehension while another pool subserves language production and that there may be other pools of resources for dealing with non-language based information. Even staunch advocates of the single resource theory of WM are now acknowledging that variability in performance on WM tasks may result from individual differences in domain specific processing efficiency (Kane et al., 1999).

2.4.2 Multi-Component Models of WM

The Baddeley and Hitch (1974) model of WM has been, to date, the most influential multi-component model to conceptualise short-term or immediate memory processes. In this model, WM is viewed as a multicomponent system that is used to retain and process information concurrently. The original model comprised a central executive and two modality specific slave systems, which are specialized in the short-term storage of verbal and visuospatial information respectively.

The central executive is less well-defined than the slave systems and has been variously described by Baddeley as a scheduler for allocating attention and as a flexible resource which can be used for both processing and storage (Baddeley, 1986). The verbal slave system is conceptualised as fractionating into two subcomponents; an articulatory subvocal rehearsal process and a phonological short-term store (loop), which retains phonologically encoded (sound based) representations of verbal information, which decay with time. The fading phonological representations can be restored by means of the subvocal rehearsal process. The visuospatial sketchpad is specialized for storage of visual and/or spatial material and is believed to be important in the short-term preservation of mental images.

Baddeley (2000) recently revised the original Baddeley and Hitch (1974) WM model and has added a fourth component, the episodic buffer. The episodic buffer is described as a limited capacity storage system, capable of temporarily holding and manipulating multi-modal information which is controlled by the central executive. The buffer allows the integration of phonological and visuospatial information from the phonological loop and the visuospatial sketch pad and interfaces with LTM.

The phonological loop has been particularly well researched and there is much support for a phonologically encoded short-term storage system. Support comes from findings such as the phonological similarity effect, the word-length effect and the effects of articulatory suppression (Vallar & Papagno, 1995).

The phonological similarity effect refers to the fact that performance in tasks of immediate serial recall is better for lists of phonologically dissimilar words such as, pen, man and ton, than for phonologically similar words such as, pen, men and ten. The word length effect concerns the fact that in tasks of immediate serial recall, using either auditory or visual presentation, memory span for short words is greater than span for long words. Finally, the articulatory suppression effect relates to the finding that the continuous utterance of an irrelevant speech sound produces a significant reduction in performance on an immediate verbal memory task. All of the above suggests that immediate verbal memory is represented in a sound-based format.

Phonetic strategies are used by beginner readers to build up whole words from their component sounds. It is therefore hardly surprising that there is a strong association between word reading skills and performance on tests of verbal WM (Gathercole & Baddeley, 1993).

Developmental increases in children's performance on phonological verbal WM tasks have been reported (Gathercole, 1998). Children's performance on tasks such as digit span increases substantially in early and middle childhood, with a large increase from two to three items at 4 years to about six items at 12 years of age. After about the age of 7 years, children learn to use a subvocal rehearsal strategy to maintain speech based information. Prior to this they are more reliant on visual memory processes. Subvocal rehearsal is an unsophisticated strategy that can be disrupted when there are dual task demands. For example, in the sentence span task, a sentence must be read out-loud when children are trying to remember the final word of a previous sentence. It can be concluded that children of primary school age have reduced verbal WM capacity relative to adults or alternatively, use their resources less efficiently.

In support of multi-component models, there is much evidence in favour of a distinction between verbal and visuospatial WM (Gathercole, 1994; Gathercole, Willis, Emslie, & Baddeley, 1992; Vallar & Papagno, 1995). There are many reports of dissociations between performance in visual and verbal WM tasks in both brain damaged adults (Hanley, Young, & Pearson, 1991) and children with developmental deficits (Baddeley & Wilson, 1993). Research investigating interference effects in dual task paradigms have demonstrated that performance is much more attenuated when both tasks are in the same modality (i.e. both visual or both verbal) than when the tasks are in different modalities (Baddeley & Hitch, 1994). Also, the bulk of the literature on neuroimaging studies suggests that there is large variability in the distribution of the activated regions in the prefrontal and posterior cortex depending on the type of WM task (Hijman, 1996). All these findings provide substantial support for the idea that separate brain areas and functional memory systems mediate performance on phonological and visuospatial WM tasks.

Most researchers now acknowledge a distinction between verbal and visuospatial WM (Gathercole, 1994). Such a distinction implies that verbal stimuli are stored in a different format to visuospatial stimuli. In addition it implies that visuospatial ability will be significantly associated with visuospatial WM and verbal ability with verbal WM. This has proved to be the case in many studies (Gathercole, 1994; Shah & Miyake, 1996). Certainly, verbal WM is strongly associated with verbal ability (Baddeley, 1998a) and is an excellent predictor of word reading skills (Cormier & Dea, 1997).

Having outlined two competing WM models, there will now be a discussion on the measurement of working memory in reading comprehension research.

2.4.3 Measurement of WM

Working memory has been measured using many different tasks. Simple and complex span tasks have typically been used to measure components of Baddeley's WM system. Simple verbal span tasks such as forward digit span, forward word span and forward sentence span have been used to estimate the capacity of the phonological loop, while forward block span (the Corsi task), which requires participants to tap out previously presented block sequences, has been used to estimate the capacity of the visuospatial sketch-pad. These skills are referred to as verbal STM and visuospatial STM respectively. Complex span tasks, which involve both a processing and a storage component, are thought to recruit the central executive in addition to the phonological loop or the visuospatial sketch-pad. These tasks, such as backward digit span or backward block span, usually involve producing information in the reverse order of presentation.

However, the most commonly used measure in reading comprehension research is a complex span task based on Daneman and Carpenter's (1980) sentence span task. The task was developed because simple span tasks such as forward digit and word span were not found to correlate well with reading and listening comprehension. The sentence span task is a dual task that involves reading a series of unrelated sentences and remembering the last word of each sentence. The concurrent reading task creates interference and prevents rehearsal of the information to be recalled. The task is presumed to require both processing and storage within the WM system. Daneman and Carpenter found that individuals with memory spans of only two or three sentence-final words did poorly on tests of reading comprehension. The average correlation between the sentence span measure and comprehension was found to be .66, with a range of between .42 and .90.

Although Daneman and Carpenter’s (1980) sentence span task, or variants of the task, are commonly used to measure children’s WM resources in research on reading comprehension, the validity of the original sentence span task has been questioned. Firstly, the original sentence span task involves reading and understanding sentences, as does reading comprehension. It has been pointed out that the high correlation between sentence span tasks and reading comprehension could really be a demonstration that sentence comprehension (i.e. reading span) is correlated with paragraph comprehension (Baddeley et al., 1985). That is, there is a strong case for arguing against the use of sentence span tasks as a measure of verbal WM since the processing component in the task is too similar to the processing required in reading comprehension.

Secondly, the task has been criticized on the basis that participants may vary in the amount of attention they allocate to the sentence reading task (Waters & Caplan, 1996). While some participants may focus on remembering the last word in the sentence and devote less resources to the reading of the sentence, others may concentrate on reading the sentence accurately and have less resources available to remember the last word in the sentence, hence performing less well in the task.

The criticisms of Daneman and Carpenter's (1980) original sentence span task have lead to the development of a number of variants of the task. Operation and counting span tasks have been developed as an alternative to sentence span tasks in order to minimize the contribution of language skills to performance. Operation span tasks involve making an arithmetic computation such as (3 x 4) + 11 = [ ], and remembering either the computed digit or a word presented on the computer screen at the end of each computation. The counting span task developed by Case et al., (1982) involves counting aloud a number of items in a visual array while keeping track of the totals of previously counted arrays.

Sentence span tasks have also been developed in which, in addition to remembering the last word of the sentence, a judgement has to be made on whether the sentence is true or false, or whether it makes sense, (Daneman & Merikle, 1996). This serves to make participants focus their attention on the whole sentence, as well as remembering the final word, thus addressing the criticism that some participants may focus only on remembering the final word. This does not however address Baddeley et al's (1985) criticism that sentence span tasks involve a similar processing component to reading comprehension.

The selection of appropriate verbal WM tasks is a critical issue in reading comprehension research. The way in which WM is operationalised is dependent on how WM is conceptualized; that is, whether it is viewed in terms of functional or structural capacity. The term “functional capacity” implies that WM performance will depend on processing efficiency and performance will vary according to expertise in the processing component of the task. The term “structural capacity”, on the other hand implies that performance is determined by the resources available to store and manipulate information generally.

There is much evidence to suggest that WM should be conceptualized in terms of functional capacity and that the level of skills in the processing component of the task impacts on performance. The results of research investigating this possibility are difficult to interpret since for example, although language skills have been demonstrated to impact on performance in verbal WM tasks (Miyake, 2001; Shah & Miyake, 1996), WM capacity may place constraints on the development of vocabulary learning (Atkins & Baddeley, 1998; Gathercole & Baddeley, 1993) and grammatical and syntactic skills (Gottardo et al., 1996; Martin & Romani, 1994; Waters & Caplan, 1996).

The preceding sections have focused on the way in which WM is conceptualized and measured. There will now be a review of the evidence that WM resources and/or WM inhibition mechanisms predict reading comprehension.

2.4.4 WM Resources

It has been proposed by advocates of the single resource model of WM that children with reading comprehension problems but normal word reading skills have a general deficit in WM resources which limits their ability to support concurrent processing and storage in all modalities (de Jonge & de Jonge, 1996; Pazzaglia, De Beni, & Caccio, 1999; Swanson, 1993; Yuill et al., 1989). From this perspective, poor comprehenders would be predicted to exhibit deficits in both verbal and visuospatial WM tasks.

Oakhill and her colleagues (Oakhill, Yuill, & Parkin, 1986; Yuill et al., 1989) demonstrated that poor comprehenders performed poorly on complex span tasks with a processing and a storage component but not on simple span tasks measuring STM. Yuill et al., (1989) used a complex memory task which involved reading aloud triplets of numbers and remembering the last number in the set, for example, reading aloud 7-4-2 and 1-3-9 and then having to recall 2 and 9. This task was developed because it was felt that skilled comprehenders may have an advantage in performing a reading span task which involves reading and understanding sentences. Poor comprehenders performed worse that good comprehenders on the task and the researchers interpreted their findings as indicating that poor comprehenders have a general nonlinguistic limitation in WM. However, Swanson and Berninger (1995) have pointed out that this conclusion is not warranted since the processing of digits is a verbally mediated task. The findings do not necessarily imply that poor comprehenders have a general WM deficit and the problem could be specific to verbal WM.

There have been further attempts to compare poor comprehenders' performance on visuospatial compared to verbal WM tasks (Nation et al., 1999; Swanson & Berninger, 1995). Swanson and Berninger (1995) found that children with deficiencies in reading comprehension performed comparably to their aged-matched peers on a visuospatial WM task but significantly worse on measures of verbal WM. Nation and her colleagues also found that poor comprehenders' deficit was specific to verbal WM and that their performance in a visuospatial WM task was not impaired (Nation et al., 1999). Similarly, in a study investigating the relationship between WM and reading comprehension in a normal population, Seigneuric et al., (2000) found that, although performance in verbal WM tasks was associated with reading comprehension skills in a group of 48 fourth-grade students, performance on a spatial WM task was not.

However, in a recent study investigating the factors underlying WM performance in children and adults, Bayliss, Jarrold, Gunn and Baddeley (2003) reported a significant relationship between reading comprehension and a measure of visuospatial STM. In their study, with a normal sample of 75 children aged between 8-9-years-old, performance on a measure of visuospatial storage (the Corsi block task presented on a touch screen computer similar to the one used in the current study) was related to performance on the Sentence Completion Forms of the NFER-Nelson Group Reading Test. Interestingly, the measure of verbal storage (forward digit span) was not related to reading comprehension in children in this study.

Bayliss, Jarrold, Baddeley and Gunn (in press) replicated the finding of a significant relationship between the NFER- Nelson Group Reading Test and the Corsi block task in a further study with 56 child participants. The correlation between the two measures was relatively high, r =.68. In contrast, the correlations between reading comprehension and verbal WM in normal samples are often much lower. For example, in a meta-analysis of the data from 77 studies, which were selected on the basis that poor readers had been excluded, Daneman and Merikle (1996) found that the average strength of the relationship between reading comprehension and language based WM tasks was only r =.41.

It must be concluded that further research is needed to clarify the relationship between reading comprehension and WM resources. The current study will address several issues pertaining to this relationship. Firstly, it seems that the relationship between reading comprehension and WM tasks is often quite weak even when no attempt is made to control for word reading skills, general intellectual ability or language skills.

Secondly, if there is a significant relationship between WM and children's reading comprehension, it is unclear whether the relationship encompasses both verbal and visuospatial WM or whether it is specific to verbal WM only.

2.4.5 WM Inhibition Mechanisms

Another theory has emerged in the literature to explain the relationship between WM and reading comprehension. It is based on the Hasher and Zacks (1988) inhibition model of WM. The inhibition model was developed to explain age-related difficulties in WM.

The inhibition model assumes that WM deficits can be a symptom of an increased susceptibility to interference due to a problem in inhibiting irrelevant information. As a result, WM becomes overloaded and the representation of concepts in WM is prolonged. The failure to inhibit irrelevant information means that spurious connections are created between items in WM, which causes interference when these items are retrieved (Banich, 1997).

The theory that reading comprehension can be the result of faulty inhibition mechanisms in WM reflects changes in the way WM is conceptualised. The change in the conceptualisation of WM has been initiated by evidence from the fields of neuropsychology and neuroradiology (Parkin, 1998). Many researchers now view Baddeley's central executive not as a single entity but in terms of a variety of processes associated with different neural substrates (Baddeley, 1998a, 1998b; Parkin, 1998; Shallice & Burgess, 1996). There is evidence that susceptibility to interference and problems in inhibiting irrelevant information is associated with abnormalities in the pre-frontal cortex (Dempster & Corkill, 1999). The frontal cortex is the last brain region to develop and does not reach maturity until young adulthood. Frontal lobe deficits causing susceptibility to interference and problems with inhibition have been linked to a range of problems including attention deficit hyperactivity disorder, learning disabilities, schizophrenia and obsessive compulsive disorder (Dempster & Corkill, 1999).

There is currently much interest in the idea that faulty or immature inhibition mechanisms are to blame for problems with reading comprehension (De Beni & Palladino, 2000; De Beni et al., 1998; Gernsbacher, 1993; Pazzaglia et al., 1999). Some of the features of narrative text which have the potential to cause interference are the presence of multiple characters which can cause interference when comprehension questions address who did what, or who is related to whom; when two or more related topics are presented in succession so that information on one topic is mistakenly attributed to the other similar topic; or the presence of irrelevant background information which can interfere with comprehension of the central theme (Dempster & Corkill, 1999).

The inhibition theory is compatible with the structure building framework theory of comprehension in which the goal of comprehension is defined as building a coherent mental representation or “structure” of the information being comprehended (Gernsbacher, 1990). According to the structure building theory, many of the processes and mechanisms involved in reading comprehension are general mechanisms which are also used in listening and picture comprehension. Gernsbacher (1990) maintains that comprehenders quickly forget the exact wording of recently comprehended information and instead recode the content into a more meaningful representation known as the “gist”.

The first process in building the structure is laying a foundation. Comprehenders use the initial words and sentences to lay the foundations of their mental structures. When the incoming information coheres with previous information, that information is mapped into the mental structure. When incoming information is less coherent, a new cognitive substructure is initiated. The building blocks of the mental substructures are memory cells. There are two mechanisms which control the level of activation of the memory cells: enhancement and suppression.

Memory cells are enhanced when the information they represent is necessary for further structure building and suppressed when this information is no longer necessary (Gernsbacher, 1990). Enhancement and suppression can be triggered by literary devices in the text, such as anaphoric pronouns, and also by context and semantic and syntactic information. The suppression mechanism is also used to dampen the activation of the inappropriate meanings of ambiguous words and the activation of the less relevant associations of unambiguous words.

The results of a series of experiments led Gernsbacher (1993) to conclude that the critical characteristic of less skilled comprehenders is their inefficiency in suppressing inappropriate or irrelevant information. On the other hand, Gernsbacher found that less skilled comprehenders do not have less efficient enhancement mechanisms and are quite capable of appreciating semantic features of the text. Poor comprehenders were found to shift to building a new substructure too often and, as a result, had a tendency to build too many substructures. Less skilled comprehenders are also less able to reject contextually inappropriate meanings of ambiguous words and the incorrect forms of homophones. They are also less able to ignore words written on pictures and pictures surrounding words.

De Beni and her colleagues also believe that an inefficient suppression mechanism can be one potential cause of poor reading comprehension (De Beni & Palladino, 2000; De Beni et al., 1998; Pazzaglia et al., 1999). She maintains that the WM inhibition hypothesis is compatible with both the general capacity hypothesis and the processing efficiency hypothesis (De Beni & Palladino, 2000). That is, if poor comprehenders have less available attentional resources they may have insufficient resources to suppress irrelevant material efficiently, resulting in poor memory performance and a high number of intrusion errors. Alternatively, the failure to suppress irrelevant information quickly and efficiently may delay higher level processes such as lexical, syntactic and semantic processing.

De Beni and her colleagues have investigated whether the inferior performance of adult and child comprehenders on sentence span tasks is a result of an increased number of intrusion errors; that is, recalled words which, although being present in the sentence, are not in the final position (De Beni & Palladino, 2000; De Beni et al., 1998; Pazzaglia et al., 1999). In sentence span tasks, in which a judgement is made on whether the content is true or false, the whole sentence must be processed and all the non-final words must be subsequently ignored. In the adult study with 44 young adult subjects (22 skilled comprehenders and 22 poor comprehenders), it was found that poor comprehenders recalled significantly fewer final words than the skilled comprehenders and also made a significantly higher number of intrusion errors (De Beni et al., 1998). This result was replicated in a small sample of 24 children (12 skilled comprehenders and 12 poor comprehenders) with a mean age of 8 years and 5 months (De Beni & Palladino, 2000). It was proposed that when the inhibitory mechanism is not working well, the child has too much information available, both relevant and irrelevant, and WM becomes overloaded (Pazzaglia et al., 1999).

Interestingly, several studies by De Beni revealed no significant differences between good and poor comprehenders on tests of either forward or backward digit span (De

Beni & Palladino, 2000; De Beni et al., 1998). At the same time poor comprehenders were found to perform worse on sentence span tasks, remembering fewer final words and also making more intrusion errors on this task. De Beni pointed out that participants may use linguistic cues in order to reject the possibility that a word was in the final position in the sentence (De Beni et al., 1998). A new measure of WM was then used in which the adult participants had to listen to a growing series of strings of animal and non-animal words. Participants were required to detect when an animal word occurred and to remember the end word from each series. Poor comprehenders recalled fewer words and made a higher number of intrusions. Semantic strategies may still have impacted on performance in this type of task however and no attempt was made to control for language skills.

It must be concluded that the evidence for deficits in WM inhibition mechanisms in children who are poor comprehenders is far from definitive. The findings are based on studies of small groups of poor comprehenders using WM tasks in which performance may well be enhanced by semantic strategies.

It has been argued that the way in which WM is conceptualized and measured is a critical issue in reading comprehension research. The discussion will now focus on methodological issues pertaining to the selection of valid measures of verbal WM and the development of visuospatial equivalents.

2.4.6 WM: Conceptual and Methodological Issues

Recent studies investigating complex span tasks suggest that both the type of stimuli (e.g., words as opposed to digits) and the type of processing (e.g., identifying a number or word that is the odd-one-out, as opposed to supplying a word to complete a sentence or a number in answer to a mathematical computation) influences not only individual differences in performance in WM tasks but also group differences in the strength of the relationship between reading comprehension and WM tasks (Bayliss et al., 2003; Daneman & Merikle, 1996; Shah & Miyake, 1996).

Individual differences in performance on verbal WM tasks have been found depending on the type of stimuli and processing required (Morra, 1994). In a large study in 191 children aged 6 to 11 years, Morra (1994) investigated intra-individual differences in performance in different types of WM tasks. The results showed relatively low correlations between different types of verbal WM tasks. For example, the correlation between backward digit span and backward word span was found to be only r =.28. That is, only 8% of the variance in performance on backward digit span is accounted for by performance on backward word span. Although both tasks use verbal stimuli there may be differences in the strategies used to remember and reorganise digits as opposed to words. Performance in backward word span may be more reliant on semantic strategies and being able to make associations between words. In view of the large intra-individual differences in performance on verbal WM tasks, Morra (1994) concluded that it is advisable to use a battery of tests in order to assess WM capacity in children, which should include tasks containing digital stimuli.

Working memory tasks which have a large language component have consistently been found to be better predictors of reading comprehension than those which are not heavily reliant on language skills. For example, in the Seigneuric et al., (2000) study which included five WM tasks, the strongest association , *r* =.56, with reading comprehension was with a WM task which involved recalling the words which did not semantically fit in with groups of words presented in sets. For example, one set comprised the words: fox, horse, hammer, and giraffe, with hammer being the odd-word-out that had to be recalled. The odd-words-out have to be recalled in the order of the sets in which they are presented. The task clearly has a strong language component since presumably children did less well on this task if they had less developed semantic ability and selected the odd-words-out incorrectly. In contrast, the relationship between reading comprehension and the task devised by Yuill et al., (1989), in which children read out groups of three digits and have to recall all the final digits in serial order, was not as strong, *r* =.45.

It is therefore important to ensure that associations between reading comprehension and WM tasks are not due to other components of the task beside the memory factor. This leads to the question, “which are the most valid WM tasks in reading comprehension research?” It seems that performance in all WM tasks will be affected to some degree by other cognitive skills. This can be minimized however by the selection of verbal WM tasks with numeric stimuli. These tasks provide a more face-valid measure of verbal WM in the context of reading comprehension research since although these tasks employ verbal symbols, performance in such tasks does not rely heavily on language skills (Daneman & Merikle, 1996; Morra, 1994).

Differences in task structure can dramatically influence the predictive power of a complex span measure, independently of task modality (Bayliss et al., 2003; Bayliss et al., in press; Morra, 1994). It is often difficult to interpret differences in performance on verbal and visuospatial WM tasks since the processing and storage requirements can be very different. It is therefore important to use verbal and visuospatial verbal WM tasks that have similar processing and storage requirements.

A variety of visuospatial WM tasks have been used in the literature since there is a lack of good standardised measures of the concept. Seigneuric and his colleagues used the "lines" task which had some similar features to the triplet number task developed by Yuill et al., (1989). Children were required to supply the third dot to complete a series of lines comprising of two coloured dots in each in a 3 x 3 grid. Children were then given coloured lines and were asked to place the lines from each set in a blank grid in the order that they were first presented. Although the task has some similarities to the triplet number task there are also important differences. The processing component in the triplet number task is to read the digits out loud, whereas in the lines task children must supply the missing dot. The storage component of the triplet number span task requires that only the final digit is recalled from the set and the previous two digits must be ignored, thereby creating a high level of interference, whereas in the lines task all the information is recalled since the lines are recalled in their entirety. Furthermore, the colour coding of the lines makes it easier for children to use verbal strategies to complete the task (i.e., the pink one goes at the bottom, the blue one goes down the right side).

In the current study the Corsi block task was used as the visuospatial equivalent of forward digit span and the triplet block task, which was based on the Corsi, was developed specifically to parallel the processing and storage demands of the triplet number task. In the Corsi, a sequence of blocks light up one after the other on a touch-screen computer and, at the end of the sequence, participants were required to press the blocks that lit up in the same order (Corsi, 1973). The task is used as the visuospatial equivalent of forward digit span since, like forward digit span, the information is recalled in the same format (sequence) in which it is presented. The backward version of the Corsi block task, which is widely used as a visuospatial equivalent to backward digit span, was not used because of evidence to suggest that it is not suitable for use in this context (Berch, Krikorian, & Huha, 1998; Gathercole, 1998; Vandierendonck, Kemps, Chiara Fastame, & Szmalec, 2004). That is, whereas performance on digit span tasks is greatly impaired by the requirement to recall in backwards order, this is not always the case for performance on backward block span relative to forward span.

The triplet block task was designed as a visuospatial equivalent of the triplet number task. In the verbal task, participants have to read aloud triplets of numbers presented on a computer screen and remember the last number from each set. In the visuospatial task developed for this study, participants have to touch sequences of three blocks as they light up on the screen and remember the position of the last block from each triplet set. Touching the blocks on the screen was introduced to have an interference effect equivalent to reading the numbers aloud on the verbal task.

Most of the evidence (refer to Section 2.4.4) suggests that there will be a significant relationship between reading comprehension and the verbal WM tasks but not between reading comprehension and the visuospatial WM tasks. However, as discussed, often the verbal and visuospatial tasks have dissimilar processing and storage demands. Also, the verbal WM tasks tend to have a large language processing component. In the current study the aim was to eliminate these problems by developing the visuospatial WM task to parallel the processing and storage demands of the verbal WM task and minimizing the effect of language skills in the verbal WM tasks by using numeric stimuli.

While the bulk of the literature on the relationship between reading comprehension and memory concerns WM, which is measured as immediate recall, there is good case for arguing that LTM, or the ability to retain and retrieve information after a delay, will be important to reading comprehension. The following section concerns the relationship between reading comprehension and verbal learning and retrieval.

2.4.7 Verbal Learning And Retrieval

Whereas there has been much research investigating the relationship between children's reading comprehension and STM, little attention has been paid to the relationship between reading comprehension and the ability to store and retrieve verbal information following a delay, which is an index of longer-term verbal learning or verbal LTM.

Working memory provides an interface between incoming information and information held in LTM. This interaction between STM and LTM was not documented in Baddeley and Hitch's (1974) original model of WM. However, Baddeley (2000; 2002a; 2002b) has recently revised his model of WM because many findings could not be accommodated by the existing model. One of the types of anomalies concerned the interface between WM and LTM. For example, a robust finding is that although participants can typically recall about five unrelated words, they can recall about 16 words if these are combined into a meaningful sentence. Such a performance is well beyond the capacity of the phonological loop.

Baddeley (2002a) concludes that there is an interaction between verbal material held in the phonological loop (STM) and that held in semantic and linguistic form in LTM. In order to allow for this interaction, Baddeley added the "episodic buffer" to his model. The principal function of the buffer is the integration of multi-modal information from both immediate and LTM. The storage capacity of the buffer is increased by the "chunking" of information, which involves integrating a number of different items into a coherent whole. Thus, the efficiency of WM in building up a representation of information in a text is not only dependent on the ability to encode incoming information but also on the interaction between the incoming information and the material already present in the long-term store; for example, declarative knowledge or semantic memory.

Ericsson and Kintsch (1995) also contend that traditional models of WM are inadequate to explain the large memory demands in complex tasks, such as reading comprehension or in expert performance. They have proposed that the WM concept should be extended to include storage in LTM, so that WM is viewed in terms of an interplay between STM and LTM resources.

Most research on the effects of LTM on reading comprehension in children concerns the effects of domain-specific knowledge. However, one study by Cain, Oakhill, Barnes and Bryant (2001) used a procedure which controlled for differences in general knowledge to investigate the differences between poor and skilled comprehenders in the retention of new verbal knowledge. They found that, following a delay, poor comprehenders had more difficulty retaining new verbal knowledge than adequate comprehenders, even when their short-term retention did not differ markedly. The measure of delayed recall was administered one week after the initial administration of the same task. Cain et al., (2001) acknowledge, however, that the results are equivocal since there were ceiling effects in performance in both immediate and delayed recall.

There is ample evidence that prior knowledge influences reading comprehension performance (Adams et al., 1995; Schneider, 1993). Adams et al., (1995) grouped 106 boys in Grades 4 to 7 on the basis of having high or low reading skill and as having high or low knowledge in a domain-specific topic (e.g., football). Comprehension was measured on two parallel texts, one of which was domain specific and one of which was in a general domain. Results suggested that domain knowledge and reading skill can be traded in order to achieve similar levels of comprehension and that specific knowledge can compensate for deficient reading ability.

Schneider (1993) conducted a review of developmental studies investigating the impact of domain-specific knowledge on memory. The review suggested that domain-specific knowledge permits children to process and recall domain-related information more efficiently, apply strategies more effectively, and integrate novel information more easily than domains for which they have less detailed knowledge. This is in-line with the conclusions in an edited book (van Oostendorp & Goldman, 1999) reviewing models of reading comprehension, mostly based on research in adults, in which prior knowledge is a key component.

There is also much evidence to show that the semantic memory system affects WM performance. When information is remembered in terms of the gist (that is, combined into a meaningful episode or “mental model”) a normal subject remembers 15 idea units compared to only 5 unrelated words remembered verbatim (Baddeley, 2002a). Individual differences in the development of semantic memory would therefore be expected to impact on performance in WM tasks. Certainly, this has been found to be the case in poor comprehenders (Nation et al., 1999). The ability to retrieve verbal information may therefore be just as critical to reading comprehension as encoding (STM) processes.

In the same way that different types of WM tasks vary in their degree of relationship with reading comprehension, the type of reading comprehension task may also affect this relationship. Although the ability to encode information in the first place is obviously related to the ability to retrieve the information at a later time, verbal retrieval can be dissociated from verbal encoding by the repetition of information to ensure that it is successfully encoded (Lezak, 1995). In this way, multiple encoding opportunities circumvent encoding problems. Consequently, when reading comprehension is measured by one read through of the text and the text is taken away prior to answering the questions, it is likely that STM or the ability to encode the information will be a strong predictor of reading comprehension.

In contrast, the ability to retrieve verbal information after a delay, with repetition of the information at the encoding stage, may be a good predictor of reading comprehension when the text is available to participants to reread. Verbal memory retrieval may also be an important predictor since information in the text may activate previously learned verbal material. In both cases, cues (that is, words or phrases) are available in the text to facilitate the retrieval of information.

2.4.8 Summary: Memory

Although there is a substantial amount of evidence to suggest that both WM and verbal LTM may be important predictors of reading comprehension, it is difficult to determine whether they will make contributions to reading comprehension beyond that attributable to the word reading and language variables. That is, it may not be necessary to add the memory variables to models of comprehension when these other types of variable are included. The strength of the relationship between reading comprehension and WM, WM inhibition mechanisms and verbal learning and retrieval will be explored both before and after controlling for word reading and language skills.

There is a good case for arguing that WM will be a less powerful predictor of reading comprehension in more naturalistic settings, when reading comprehension tests are self-paced and the text is available to re-read when answering the questions. In this context, measures of the ability to retain and retrieve verbal information following a delay may be better predictors of reading comprehension. Most research suggests that reading comprehension is associated with verbal but not visuospatial WM. These findings are however, difficult to interpret since first, the verbal and visuospatial tasks have very different processing and storage requirements, and secondly, the verbal tasks have a large language component, making it impossible to tell whether the relationship between reading comprehension and the verbal WM tasks is underpinned by language skills. Working memory tasks were specifically designed and selected for the current research to try to eliminate these problems.

2.5 Reading Comprehension: Conceptual and Methodological Issues

It has been argued that the conceptualization and measurement of WM is critical to reading comprehension research. Similarly, the way in which reading comprehension itself is defined and measured is fundamental to research in this area.

For the purposes of the current study, reading comprehension has been defined as the extraction of meaning from text. It is therefore necessary to select a measure of reading comprehension, which is appropriate in this context. In the following discussion, the implications for the selection of different types of reading comprehension tests will be considered and also how different question types may affect performance.

2.5.1 Measures of Reading Comprehension

There are different types of measures of reading comprehension and the type of measure selected for research reflects how reading comprehension is being conceptualised. The type of measure used has the potential to influence the results of research investigating the relationship between the comprehension test and other cognitive variables.

There are two broad types of reading comprehension tests; namely, tests in which the complete text is presented followed by the questions and tests which rely on “cloze” procedures (requiring the input of missing words). Two important features of the first type of reading comprehension test, in which the text is presented followed by the questions, are the extent to which comprehension scores are dependent on 1) word reading skills and 2) memory. The answers to both types of test can be presented in an open or a multiple-choice format and this may also affect performance. It will be argued that in the current context, when reading comprehension is defined as the ability to extract meaning from text, multiple choice tests, in which children read the text to themselves unaided and questions are answered with the text available, are the most ecologically valid method of measurement.

Reading comprehension tests such as the The Neale Analysis of Reading Ability – Third Edition (Neale, 1999), in which the text is presented followed by the questions, vary on the degree to which comprehension scores are dependent on word reading skills, according to the method of administration. The Neale is commonly used to measure reading comprehension since it conveniently provides measures of word reading skills and reading speed, as well as reading comprehension. The test requires that participants give oral responses to questions presented orally in the absence of the text. Children answer the comprehension questions after one read through of the text during which word reading errors, or omissions, are corrected by the examiner. The reliance on oral questioning techniques and the correction of word reading errors means that comprehension scores may be dissociated from word reading scores. This is useful when the objective is to investigate causes of reading comprehension deficits other than poor word reading skills. However, it is problematic when the aim is to formulate a comprehensive developmental model of reading comprehension, since text comprehension is normally, at least in part, dependent on word reading skills.

Another important issue in relation to tests in which the text is presented with the questions, is the extent to which tests confound comprehension of the text with memory of the text. Tests in which the text is removed prior to answering the questions, such as the Neale, can be criticized because they measure not only the ability to extract information from the text, but also memory for details in the text in such a way that the two cannot be separated. In the Neale, not only do participants have to remember the contents of the text which they are required to read aloud to the examiner, they also have to remember the questions which are presented orally by the examiner, although these can be repeated. Measured in this way comprehension would be expected to correlate more highly with measures of verbal STM and presumably also with measures of verbal learning and retrieval (or LTM).

On the other hand, the second type of reading comprehension measure, such as Tests of Reading Comprehension (TORCH) (ACER-Press, 1987), or forms X and Y of the NFER Group Reading Test (NFER-Nelson, 1998) rely on "cloze" procedures and require the input of missing words. Performance in these tests may correlate more with language skills. The provision of missing words requires that children follow the meaning of the text and have good semantic and syntactic skills. In fact, children's performance in cloze tasks correlates highly with their performance in syntactic awareness tasks and cloze tasks are often used as a measure of syntactic skills (Tunmer, Nesdale, & Wright, 1987).

Children with poor verbal skills may perform particularly poorly on such tests, since, as the test progresses, errors can compound and earlier errors can interfere with understanding of the ensuing narrative. Cloze tests are not dependent on memory since the text is available to children as they fill in the gaps. Tests which require written answers may however be difficult to interpret if children have poor hand-writing or poor written English skills. To circumvent this problem, "cloze" tasks often come in a multiple choice format (e.g., the NFER Group Reading Test (NFER-Nelson, 1998), although performance in such tasks would still be expected to be strongly associated with language skills.

Reading comprehension is normally achieved by reading to oneself, as opposed to reading aloud, with the text available, allowing ambiguities to be resolved by re-reading the relevant sentences. In this context, reading comprehension may be more reliant on word reading skills and the ability to integrate information in the text, than memory for specific details. This is the case in multiple choice tests of reading comprehension in which children read passages at their own pace and select the appropriate answers to questions from a range of potential responses while referring back to the passage if the need arises. Such tasks measure only the ability to extract and integrate information from the text, rather than memory for information in the text. The use of multiple choice methodology also ensures that the measurement of comprehension is not confounded by other factors, such as poor hand-writing or poor written English.

On the other hand, some researchers have questioned the validity of multiple choice tests (Drum, Calfee, & Cook, 1981; Farr, Pritchard, & Smitten, 1990; Freedle & Kostin, 1994). The major criticism is that a better-than-chance performance can be obtained without reading the whole of the text passages. In one research study (Farr et al., 1990), 26 college students were found to adopt four main strategies to complete the Iowa Silent Reading Test which has a multiple choice format. The first was the expected strategy of reading the passage before turning to the questions, the second was to partially read the passage before turning to the questions, while the third was to read through all the questions and then read the entire passage and the fourth was to read each question and then immediately search for the correct answer in the passage. As the test progressed many students were found to change strategies and while over 50% of them started by reading the passage before answering the questions, there was a tendency to change to a strategy of going straight to the questions prior to reading the passage.

The question is whether the adoption of different strategies to complete reading comprehension tests, especially question-first strategies, in which questions are read before the passages and the text is skimmed for the answers, affects the construct validity of multiple-choice reading tests? Daneman and Hannon (2001) investigated this possibility in 48 college students. They found that although participants could achieve a better-than-chance performance without reading the whole passage, those who read the passages more thoroughly (either before or after reading the questions) achieved better scores. Those who did not read much of the passage at all demonstrated the poorest performances, those who used the questions to search for the answers in the text without totally reading the passages demonstrated an intermediate level of performance, while those who read the entire passage first and then reread sections of the passage to answer specific questions, demonstrated the highest level of performance. The researchers concluded that the results implied that multiple-choice measures were a valid method of assessing reading comprehension, as long as test takers engaged in at least some reading of the passages.

A factor in favour of tests such as the Neale Analysis of Reading Ability is that children have to read the whole of the reading passage and cannot skim the passage to obtain information. However, this advantage may be negated by the fact that children are required to read the passages aloud to an examiner so that a word reading score can be obtained and the examiner corrects any errors. Children may therefore be very susceptible to performance anxiety in this type of task and test anxiety has been found to have a negative impact on achievement (Kestenbaum & Weiner, 1970). Although it has been argued that the correction of word reading errors on the Neale and the use of an oral question and answer format may dissociate comprehension from word reading skills, it is also possible that when measures of comprehension and word reading are taken from the same test, comprehension is more dependent on word reading since better readers, whose word reading skills are more automatic, can devote more attention to comprehending the text (Perfetti, 1985).

There has been some discussion of whether epistemic knowledge (knowledge about knowledge and learning) can lead test-takers to select the most effective strategy to obtain better scores. Research investigating the validity of multiple-choice measures of reading comprehension has been conducted with adult samples that are frequently university students. Presumably these well-educated adults, who, no doubt, have had extensive experience with multiple choice methodology, are much more sophisticated in their approach to test taking than children in primary school. This is not to say that children of this age will not adopt a question first strategy with minimal reading of the test (although this is likely to result in a lower score) but they may be less likely to use epistemic knowledge to select a test-taking strategy. The issue affecting construct validity in children may therefore be the question of motivation rather than the selection of the test strategy *per se*.

Finally, another factor favouring multiple-choice tests is that they do not have to be administered to each child individually and can be administered to groups. Many studies on children's reading comprehension have very small sample sizes making the results obtained tentative since the studies lack statistical power. Multiple-choice tests are therefore advantageous since they facilitate data collection, making it feasible to have larger sample sizes.

In summary, reading comprehension measures in which the text is presented followed by the questions in a multiple-choice format, with the text remaining available when answering the questions, offer some advantages over other types of reading comprehension tests. Most importantly they ensure that only the ability to extract information from the text is measured, rather than children's memory for details in the text. Although multiple-choice tests have been criticized because participants do not have to read the text passages to answer the questions, participants who adopt this strategy have been found to obtain lower scores. Multiple-choice is a convenient methodology since it allows reading comprehension tests to be administered to more than one child at a time, facilitating the collection of data on large samples.

2.5.2 Types Of Reading Comprehension Questions

Tests of reading comprehension may vary according to the types of questions the test comprises. Different question types may draw on a different range of cognitive skills The types of questions in a comprehension test and the proportion of each type can therefore be expected to impact on which variables are identified as the strongest predictors of reading comprehension.

Comprehension questions can be divided into two basic types. The first type involves a literal interpretation of the text. The answer can either be obtained from information explicitly stated in the text (e.g., “On Tuesdays he goes to the market”. Question: “Where does he go to on Tuesdays?”), or by rewording or rephrasing information in the text (e.g., “Trees with lots of berries were favourite perching places for the birds”. Question, “Which trees attracted most birds?”).

The second type of question requires making an inference. An inference is information that is implied from (rather than directly stated in) the text. For example, in order to answer the question, “how do you think the farmer felt at this time?” from the sentence, "the drought had continued for five years and the farmer had to shoot many of his animals", a child must infer the farmers state of mind from the information given. The work of Cain and Oakhill and their colleages suggests that the ability to make an inference by integrating information in the text is heavily dependent on WM resources, even when the text is available to control for memory problems (Cain & Oakhill, 1998; Cain & Oakhill, 1999; Cain et al., 2001; Oakhill, Yuill, & Parkin, 1988; Yuill & Oakhill, 1991).

Inferential questions can be classified on two dimensions; whether they are coherence or elaborative inferences (Garnham, 1989) and whether they require making an inference on local or global information in the text. Coherence inferences are necessary to establish links between premises in the text (e.g., "Jack had thrown Richard to the ground and was about to jump on him. John quickly rushed to his aid", is comprehensible if the reader knows that John is a friend of Richard's). Generation of a coherence inference therefore requires the integration of different pieces of information from within the text. In contrast, many elaborative inferences require the integration of information from the text with prior or general knowledge (e.g., in the sentences, "Jennie stepped off the curb without looking either way. After an explosion of pain and blackness, she awoke to the smell of antiseptic and a woman in a uniform at her side", prior knowledge about the world tells the reader that Jennie is crossing the road and subsequently wakes up in hospital after being run over).

Inferential questions can be further categorized according to whether they are based on local (single or consecutive sentences) or global (scattered sentences) information. An example of an inferential question that requires information to be drawn from different parts of the text is, "what do you think would be a suitable title for this story?" Although more sophisticated taxonomies of the types of inferences children make in story comprehension have been developed (Nicholas & Trabasco, 1980), the simple taxonomy outlined above was deemed appropriate for the current study.

The composition of the question types in a reading comprehension test may influence the results of studies such as this one investigating the strongest cognitive predictors of comprehension. The first type of question outlined above, in which the answer can be drawn verbatim from a single sentence, is obviously much easier than the other types, especially when the text is available. Children can scan the text to find all the necessary information in a single sentence. Alternatively, when information has to reworded or rephrased, a correct answer is dependent on vocabulary knowledge and/or syntactic skills. This is in contrast to questions that require inference making which may rely on prior knowledge or alternatively, the ability to integrate information from the text, which may be more dependent on WM. It can be concluded that measures of reading comprehension should incorporate all of these different question types. A breakdown of question types using the classification system outlined above for both the reading and oral comprehension tests used in the current research is presented in Table 3.3 in the Method section.

2.6 Summary of Aims

The study had two major aims. The first was to develop a model to account for children's reading comprehension in a normal sample when the text is available, that is superior to traditional models, such as the *simple view* (Gough & Tunmer, 1986), which incorporate only oral comprehension and phonological recoding. Many studies exclude children with poor word reading skills or match children on this ability. However, when the aim is to develop a comprehensive model or reading comprehension, rather than to investigate the specific causes of reading comprehension deficits, word reading skills cannot be excluded.

The measures selected for possible inclusion in the model were implicated as being important to children's reading comprehension in the preceding review of the literature. The measures fell into three categories: 1) word reading, 2) language skills and 3) memory. Age and general intellectual ability (Tramontana et al., 1988) are known to be highly correlated with outcome and therefore the effects of these variables were taken into account. The intention was to formulate a model of reading comprehension by identifying the strongest independent predictors from each of the three groups of predictor variables, after controlling for age and general intellectual ability. The predictive power of such a model was compared with the predictive power of both multiplicative and additive forms of *the simple view.*

The second major aim was to investigate the relationship between reading comprehension and different types of memory tasks. Research suggests that the strength of the relationship between reading comprehension and memory varies according to the nature of the memory task (Daneman & Merikle, 1996). The current study was unique in incorporating a large number of different types of memory tasks. The tasks included measures of STM, WM and a task assessing longer-term learning and retrieval. Tasks were presented in both the verbal (with numeric and word stimuli) and visuospatial modalities. The aim was to identify the strongest predictors of reading comprehension and the pattern of inter-relationships amongst the memory measures.

CHAPTER 3. METHOD

3.1 Participants

Participants were recruited from two primary schools in Melbourne suburbs that were selected to represent a broad range of socio-economic status (SES). Forty-seven percent of the sample attended the primary school in the suburb where the population was predominately low SES, compared to 53 percent from the school in the suburb where the population was predominately upper middle SES. The population of the suburb with low SES had greater ethnic diversity. Children were required to have English as their first language.

The sample consisted of 180 primary school children in grades 3 to 5. Descriptive statistics of chronological age, reading age on the Woodcock Reading Mastery Tests-Revised (Woodcock, 1998) and extrapolated IQ on the Ravens Standard Progressive Matrices (Raven, 1958) are given in Table 3.1 for each grade. The children’s ages ranged from 8 years 7 months to 11 years 11 months, with a mean age of 10 years 2 months. The mean reading age of the sample was 10 years 9 months (range 7:8 to 17:8), whilst IQ ranged from 85 to 143, with a mean score of 106.

Table 3.1

Mean, Standard Deviation, and Range of Chronological Age, Reading Age (in years and months) and IQ for each Grade

Grade	*n*	*Measures*	*M*	*SD*	Range
3	54	Chronological Age	9:3	0.40	8:7 – 10:8
		Reading Age	10:2	1:46	7:10 – 15:3
		Extrapolated IQ	106.0	13.94	85.0 – 140.0
4	80	Chronological Age	10:2	0.40	9:1 – 11:2
		Reading Age	10:9	1:83	7:11 – 17:8
		Extrapolated IQ	106.8	15.69	86.0 – 143.0
5	46	Chronological Age	11:3	0.45	10:1 – 11:11
		Reading Age	11:5	1:97	7:10 – 17:8
		Extrapolated IQ	105.4	14.35	85.0 – 135.0

3.2 Materials and Administration

A total of 16 tests were included in the test battery. Many are standardized tests which were carefully selected on the basis that they were the best and purest measure of the concept and were commonly used to measure that cognitive skill in the research literature. The test of reading comprehension was selected in association with staff at the Australian Council of Education Research. A wide range of memory tests was used, including tests with numerical, word and visuospatial stimuli. A description of all the tests and procedures for administration is provided in this section. A summary of the tests and their sources is given in Table 3.2 prior to providing a description of each in the following section.

Table 3.2

Summary of Tasks

Type	Task	Source
Reading Comprehension	Progressive Achievement Test in Reading Comprehension (PAT Reading-Revised) Form B	ACER (2000)
	Concurrent Validity Achievement Improvement Monitor (AIM)	Victorian Department of Education (2000)
Control	General Intelligence Ravens Progressive Matrices	Raven (1958)
Measures	Word Reading Age Word identification subtest from Woodcock Reading Mastery Tests-Revised (Form G)	Woodcock (1998)
Word Reading	Phonological Recoding Nonword Reading Test	Martin & Pratt (2000)
	Orthographic Processing Irregular Word List	Manis, Seidenberg, Doi, McBride-Chang & Petersen (1996)
	Text Reading Accuracy and Reading Speed Neale Analysis of Reading Ability-3rd Edition (Form 1)	Neale (1999)
	Exposure to Print Title Recognition Test	Adapted from Cunningham and Stanovich (1990)

Table 3.2
Summary of Tasks

Language	Oral Comprehension	ACER (2000)
	Adapted from PAT Reading Revised Form	
	Receptive Vocabulary	Dunn & Dunn (1997)
	Peabody Picture Vocabulary Test-3rd Edition (PPVT-III)	
	Receptive Grammar and Syntax	Bishop (1983)
	Test for the Reception of Grammar (TROG)	
Memory	Short-Term Verbal Memory	
	Forward Digit Span	Wechsler (1996)
	Rey Auditory Verbal Learning Task (RAVLT)	Spreen & Strauss (1998)
	Verbal WM	
	Backward Digit Span	Wechsler (1996)
	Triplet Number Task	Adapted from Yuill, Oakhill & Parkin (1989)
	Short-Term Visuospatial Memory	
	Corsi Block Task	Milner (1973)
	Visuospatial WM	Visuospatial equivalent of Triplet Number Task
	Triplet Block Task	
	WM Inhibition	Spreen & Strauss (1996)
	Intrusions on the RAVLT	
	Verbal Learning and Retrieval	
	Delay trial on the RAVLT	Spreen & Strauss (1996)

3.2.1 Reading Comprehension

Progressive Achievement Test in Reading Comprehension (PAT-Reading-Revised) Form B

The measure of reading comprehension was the Progressive Achievement Test in Reading Comprehension (PAT Reading-Revised) Form B, Years 3-5 (ACER-Press, 2000) which is an Australian test that was normed nationally on a sample of 55 primary schools. The sample included State, Catholic and Independent schools proportional to their occurrence in the total Australian school population. There were 1070 grade 3 children (mean age 9-0), 998 grade 4 children (mean age 10-0) and 374 grade 5 children (mean age 11-0).

The PAT Reading-Revised comprises two booklets, the test passages booklet and the answer booklet. The test passages booklet contains the eight reading passages which are graded in their level of difficulty and range in length from 118 words to 339 words. It contains reading passages with a diverse range of topics including a fairy story, a description of a recipe, wild-life and a family discussion. A broad range of topics is desirable since it has been found that the choice of topics can potentially impact on children's motivation to complete the test (Boyd, 1973; Kellmer-Pringle & Neale, 1957).

The answer booklet contains 39 multiple choice questions covering the eight reading passages. Four alternative answers are given for each question. The test was administered according to standardized instructions. Children were told that the PAT is a test of how well they understand what they read and that they should read each story carefully and then answer the questions about it before going on to the next story. They were instructed to select the correct answer from four possible options for each question. The examiner went through a practice example with a passage and two questions to make sure that children understood what to do. Children were informed that they had 40 minutes to complete the test and that they should work as quickly and as carefully as they can. They were also told to answer each question even though they might not be sure of the answer but not to spend too much time on questions that they found hard. Children were also told that if they make a mistake they should erase it carefully and then select the correct answer.

As discussed in Section 2.5.2, reading comprehension questions can vary from requiring simple verbatim answers to more complex inferences across several sentences. The PAT was selected on the basis that it contains the full range of comprehension question types and while some of the questions in the PAT could be answered using a variety of strategies, two expert raters classified the questions and agreed that nearly half of the questions (17/39) definitely required an inference to be made. The majority of these inferential questions were of the global coherence type, which draw on information from different parts of the text and do not rely on previous knowledge. It was thought to be particularly important to ensure that the test contained an adequate number of inferential questions, given the importance assigned previously to WM and noting that the text was left in front of the child. The question types in the PAT are listed in Table 3.3.

The reliability and validity of PAT-Reading Revised Form B are high. Measures of reliability reported in the manual (based on the K-R 21 formula) were .85 in grade 3 children, .85 in grade 4 and .83 in grade 5. The standard error of measurement was 2.9 in grade 3 children, 2.8 in grade 4 children and 2.7 in grade 5 children. The concurrent validity of the test is high and the correlation with Forms X and Y of the Group Reading Test II (GRT II) (NFER-Nelson, 1998) which are two alternate form multiple choice cloze comprehension tests, in which the correct word to complete a sentence has to be selected from five alternatives, are r =.81(X) and r =.85 (Y).

The children's reading comprehension scores on the PAT-B were also found to correlate highly with their scores on the English test from the Achievement Improvement Monitor (AIM). The AIM was launched in July 2000 and comprises a series of state-wide tests which are administered annually to children in grades 3 and 5 in all Victorian primary schools. The tests measure reading comprehension (English), writing, spelling, number

Table 3.3
Types of Comprehension Question

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1. QUESTIONS REQUIRING A LITERAL TRANSLATION OF THE TEXT

- **Can be answered from information taken verbatim from the text.**

For example: Text: Step 5: Beat the egg and cream together with a folk. Question: What is the mixture mentioned in step 5? Answer: Egg and cream.

- **Can be answered by rewording or rephrasing information in the text**.

For example: Text: It lays four white, purple-spotted eggs in a nest usually built near a convenient supply of food. Question: Where does the passage tell us the nest is built? Answer: Where food is easily found.

2. QUESTIONS REQUIRING THE MAKING OF AN INFERENCE

- **Can be based on locally or globally presented information**

Locally presented information (single or consecutive sentences).
For example: Text: The half-grown cat, thin and wild, stood by itself on the edge of the verandah, ready to dive into the shelter of the rosebush at the first threatening move. ……..As Cathy fed the bantams and collected the eggs, the green eyes glinted in the gloomy corner of the shed behind the feed bin. Question: The green eyes belonged to? Answer: The cat.

Globally presented information (integration of knowledge from the whole text)
For example: Question: This passage is set in? Answer: An Australian home.

- **Can be of the Coherence or Elaborative Type**

A coherence inference establishes links between premises in the text which does not require prior knowledge.
For example: Text: Many years ago in New Zealand the weka was the constant companion of explorers and bushmen, because it was so interested in their tents and what they contained. Question: Where were early explorers most likely to see the weka? Answer: Around their camps.

An elaborative inference requires the integration of information from the text with prior or general knowledge.
For example: Text: Decorate the dish with a sprig of parsley
Question: You add the parsley so the food will….? Answer: Look nice

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and mathematics. The majority of questions on the reading comprehension test in the AIM are presented in a multiple choice format and entail answering questions on story passages which children read themselves and which they have in front of them when answering the questions. In the current study, there was a reasonably high concurrent validity between performance on PAT reading comprehension and performance on the AIM Reading Test (r =.72, p<.001).

3.2.2 Control Measures

General (Non-Verbal) Intellectual Ability

Ravens Standard Progressive Matrices (Raven, 1958) was used as a measure of general non-verbal ability with the Australian norms developed by the Australian Council for Educational Research (de Lemos, 1989). The 20 minute timed group administration of the test was used in this research. The 1986 Australian re-norming of the Standard Progressive Matrices by the ACER was based on the 1958 edition of the test. Australia-wide norms were taken for both a timed and an un-timed administration. Sample size was 4,069 for the timed administration and 4,158 for the un-timed version and the age of students in the re-norming study ranged from 8 to 17 years. Over 50% of each sample was from Victoria or New South Wales and the majority of children had an Anglo/Australian background. That is, children from other ethnic backgrounds were not well represented.

The test is described in the Australian manual as a measure of general non-verbal reasoning ability (de Lemos, 1989). It was first published in 1938 and revised in 1948 and again in 1956. The test was developed in Britain as a measure of Spearman's *g*, which is believed to be relatively independent of cultural or educational experience (Catell, 1963; Jensen, 1980). It has been widely used as an assessment tool in clinical, educational and research contexts.

The test comprises a question booklet and an answer sheet. The question booklet contains 60 items arranged in five sets of twelve. The items are numbered one to twelve within their sets (sets A to E). The items in each set are of a similar type and become progressively more difficult. Each item is presented on a different page and is in the form of a pattern in which one piece is missing. The object is to select a piece of the pattern from six or eight alternatives in order to complete the pattern correctly. The answers are recorded on the answer sheet by shading in the number of one of the six to eight alternatives next to the corresponding set and item number. The test was administered according to the standardized instructions for administration of the Standard Progressive Matrices as a timed test in the test manual (de Lemos, 1989). Children were told that they had to select one of six pieces (marked 1-6) to complete a pattern and to mark their answers on the sheet provided. They were also told that the patterns gradually become more difficult but that they should not spend too long on each question. Children were informed that they had twenty minutes to complete the test.

Estimates of the reliability co-efficients of the timed version of the Standard Progressive Matrices in the Australian sample reported in the manual range between .80 and .88 in grades 3 to 5 and the standard error of measurement ranges between 3.54 and 3.60 (de Lemos, 1989). With respect to validity, performance on the Standard Progressive Matrices was found to correlate well with performance on other non-verbal tests of ability (Jenkins Non-Verbal Test r =.76 and ACER Test of Reasoning Ability r =.63) and reasonably well with performance on verbal ability tests (ACER Word Knowledge Test Form E r =.43 and Form F r =.49) and with teacher ratings of ability (General Scholastic Ability r =.43, English r =.40).

Word Reading Age

Word reading age was calculated from the raw scores on the word identification subtest of the Woodcock Reading Mastery Tests-Revised (WRMT-R) which is a revision of the 1973 Woodcock Reading Mastery Tests (Woodcock, 1998). Normative data for the WRMT-R were gathered from 6,089 subjects in 60 different geographical locations in the United States. Subjects were randomly selected using a stratified sampling design that controlled for specific community and subject variables.

The Word Identification subtest of the WRMT-R involves reading isolated words that appear in large type on the pages of a test booklet. The test contains 106 word items arranged in order of difficulty. The word composition approximates the distribution of regular and irregular words in the English language with more regular words than irregular words. The starting point of the test varies according to age with older subjects commencing at a later point. A basal point of entry is established after six consecutive correct responses and a ceiling is established after six consecutive incorrect words, ending with the last word on the page of the test booklet. The test was administered according to the standardized instructions in the test manual (Woodcock, 1998).

The reliability and validity of the WRMT-R reported in the manual is high (Woodcock, 1998). The split half reliability co-efficient of the Word Identification subtest is calculated to be .97 in Grade 3 children and .91 in Grade 5. The standard errors of measurement are 3.8 and 6.1 respectively. According to the manual, when the WRMT-R was developed, care was taken to assure content validity by seeking the contributions from outside experts such as experienced teachers and curriculum specialists. The concurrent validity of the WRMT-R is high with correlations of between .78 and .92 with performance on other tests of reading achievement such as the PIAT Reading, Iowa Test of Basic Skills (Total Reading), WRAT Reading and WJ Reading Achievement, reported in the manual.

3.2.3 Word Reading

There were three different measures of word reading accuracy: a nonword reading test which provides a measure of phonological recoding skills, the Martin and Pratt

Nonword Reading Test (Form A) (Martin & Pratt, 2000), an irregular word reading test which provides a measure of orthographic processing skills, an irregular word list developed by Manis et al., (1996) and a text reading measure, a grade-appropriate passage from the Neale Analysis of Reading Ability-3rd Edition (Form 1) (Neale, 1999), which provided a measure of word reading accuracy and reading speed. There was also a measure of exposure to print and reading experience, the Title Recognition Test (TRT), based on one developed by Cunningham and Stanovich (1990).

Phonological Recoding:

The phonological recoding task was the Martin and Pratt Nonword Reading Test (Martin & Pratt, 2000). The Martin and Pratt Nonword Reading Test is a test of phonological recoding skills which can be administered to children from 6 to 16 years. It was developed in Australia and age-norms are provided. The test was standardized on 863 students attending schools in Southern Tasmania. Participating schools were selected using a stratified sample design to match the 1991 census population of socioeconomic characteristics of government schools in that region. Students were tested on both Forms A and B.

The 54 nonword items in the test all conform to acceptable letter-sound correspondences in English and reading them is like reading regular words that have not been encountered previously. There are two forms of the test, form A and form B, and form A was used in this research. The test was administered according to the standardized instructions in the test manual (Martin & Pratt, 2000). Children are tested individually and are required to read the nonword items aloud to an examiner. The nonword items were presented in large font, six to a page on separate pages bound in a folder. All children begin on the first practice item and, after attempting all seven practice items, proceed with the test. Testing is discontinued when the student has failed on eight consecutive items.

The reliability and validity of the Martin and Pratt Nonword Reading Test are reported in the manual as being high (Martin & Pratt, 2000). The test-retest reliability co-efficient of form A is .96 (based on interval scores) and the alternative form reliability (form B) co-efficient is .95. The standard error of measurement is 2.9 (based on raw scores). The Martin Pratt Nonword Test also performed well on measures of validity with correlations of .89 and .93 with other nonword tests and correlations between .78 and .88 with four different word-reading tests.

Orthographic Processing

The orthographic processing task was an irregular word list developed by Manis et al., (1996) to investigate different subtypes of developmental dyslexia. An irregular word is one that cannot be read correctly using solely a phonological strategy, for example, “yacht” or “iron”. That is, irregular (or exception) words cannot be read by correctly combining the phonemes corresponding to the graphemes in the word.

The list comprises 44 irregular words which were selected from a frequency-graduated list designed by Adams and Huggins (1985) in a study undertaken in Boston, America. The frequencies of the words ranged from 134.1 per million to 0.12 per million according to Caroll, Davies, and Richman's (1971) dispersion adjusted norms (U-scale). The words were selected from a set of 80 used in the pilot testing with 80 children in order to exclude words that were either too easy or too hard, given their frequency, or words which were beyond the children's speaking or listening vocabularies.

The words were listed in decreasing order of frequency and were printed on two sheets of paper (lower case, Ariel, 24 point). Children were told to read the words in the list as accurately as possible. In the current study the test was discontinued after 6 consecutive errors. In the original Manis et al., (1996) study all of the words were administered to all of the subjects but this method of administration was not used because continuing with all word items could lead to distress and loss of motivation in children who were unable to read even the first words on the list.

Text Reading Accuracy and Speed

The Neale Analysis of Reading-3rd Edition is a standardized test that can be used as a measure of children's word reading accuracy, reading speed and comprehension skills. In the current study it was used as a measure of word identification skills and text reading speed. The test is based on the original version of the Neale which was developed in the United Kingdom during the 1950's (Neale, 1999). Different versions of the test have been used as an assessment tool in a substantial body of research. The 3rd Edition of the Neale was standardised in Australia using a stratified random sampling procedure. It was administered to 1394 students from 116 schools across Australia.

The test comprises a series of unrelated narratives which children read out-loud to an examiner from a reading book. Form one of the Neale Analysis of Reading Ability-3rd Edition comprises six narratives that are graded to present six levels of increasingly difficult vocabulary and complex grammar aimed at children from 6 to 12 years. In the standard administration, the starting point of the test varies according to age with older subjects commencing at a later point. The test is discontinued after a designated number of errors (words read inaccurately) are exceeded. However, for the purposes of this study, the test was not administered in accordance with the instructions in the test manual. Children were required to read only one age-appropriate passage. That is, grade 3 children read “Ali” which contains 73 words, the grade 4 children read “Jan” which contains 96 words and grade 5 children read “The Fox” which contains 117 words. Children read the narrative passage and the number of decoding errors and the time taken to read the passage was noted. Children were told that the test was a measure of reading ability and they were instructed to read the passage as accurately and quickly as they could. The time taken to read the passage was recorded.

The reliability and validity of the Neale Analysis of Reading-3rd Edition (1999) are high. Parallel form reliability co-efficients for Form 1 ranged from .81 to .90 for reading speed and from .89 to .97 for reading accuracy in the 9 to 12 age group. Internal consistency reliability co-efficients ranged between .94 and .95 for reading speed and from between .95 and .96 for reading accuracy in grades 3 to 5. Standard errors of measurement for Form 1 ranged from 5.82 to 6.42 for reading speed and from 4.49 to 3.95 for reading accuracy in the 9 to 12 age group. According to the manual, the Neale test has high content validity since narrative passages were carefully selected to be representative of the subject matter typically assessed in the 6 to 12 age group. Performance on the Neale has been found to correlate significantly with performance on other tests, such as the Holborn Reading Test, the Kelvin Reading test and the Vernon and Schonell Reading Tests, which are accepted amongst professionals as being measures of reading ability.

Exposure to Print

A measure of exposure to print was devised based on the Title Recognition Test (TRT) which has been found to be a robust predictor of print exposure in children (Cunningham & Stanovich, 1990). The original TRT comprises a list of book titles in which real titles are embedded amongst foils. The foils eliminate the problem of socially desirable responding, and the problem of contamination by inaccurate estimates of the frequency of reading activities. The test was constructed as an alternative to the Author Recognition Test developed for use with adults (Stanovich & West, 1989).

The original version of the TRT consisted of a total of 39 items: 25 actual children's book titles and 14 foils for book names. However, in order to equate the probability of selection of a foil to the probability of selection of a real book title, the current version of the TRT was constructed with the same number of foils and titles. In total, there were 20 authentic children's book titles and 20 foils. The authentic book titles were selected in consultation with Ward Sagar, a leading children's bookseller in Melbourne, who advised on reading trends in children's literature at the time of the research. The titles chosen cover a wide range of types of literature and reading ages from pre-school to the latter years of primary school.

Children were told that the object of the test was to see if they could recognize the titles of some real children's books and ignore fake or made up titles. Then children were directed to have a look at the practice question on the front of the test sheet as follows:

> *Here are some book titles. Some of them are made up and some of them are real titles of published children's books. All I want you to do is put a tick by the side of the real books and ignore the fake books. So looking at the first one, has anyone heard of the Tale of Peter Smith. No, that's not a children's book title so we leave*

that one. Now, the second one, the Tale of Peter Rabbit. Yes, that's a children's book by Beatrix Potter so we tick by the side of it. Now look at the third one, the Lion, the Witch and the Wardrobe. Yes, that's a book by C.S. Lewis so we tick that one too. The last one, Kate's School Holidays – has anyone heard of a book called Kate's School Holidays – No. So we leave that one. Ok. Do you all understand what you have to do? You can turn the page and make a start. Take your time, there's no need to rush.

Children were told that titles could be read aloud to them if they had any difficulty reading the words. They were then required to study the list of books, which was printed on two pages, and to tick the titles that they recognized as being real books. No time limit was imposed. A copy of the test is provided in Appendix 1.

3.2.4 Language

There were three language measures: a test of oral comprehension based on PAT Reading-Revised (Form A), a test of receptive vocabulary, the Peabody Picture Vocabulary Test-3rd Edition (PPVT-III) (Dunn & Dunn, 1997) and a test of receptive grammar and syntax, the Test for the Reception of Grammar (TROG) (Bishop, 1983).

Oral Comprehension

The measure of oral comprehension was adapted for oral presentation from PAT Reading-Revised (Form A) Years 3-5 (ACER-Press, 2000). The measure comprised one answer booklet containing 28 multiple choice questions on six different stories presented on a tape recorder. For two of the stories, the entire story was presented followed by all of the questions. For the other four story passages, which were longer, the stories were split into two parts with questions presented after each part.

A number of steps were taken in order to minimize the impact of word reading skills on test performance. Questions for each story passage were printed on separate pages in the booklet and children turned to the relevant questions just prior to the passage being played on the tape recorder. The questions and four answer alternatives were read aloud to the children after the passage had been presented on the tape recorder and children were instructed not to mark their answers on the sheet prior to this. Information was repeated as necessary.

PAT-Revised Form A is a parallel form of PAT-Revised Form B. As with Form B, Form A contains questions that can be answered verbatim from the text or by rewording, or rephrasing parts of the text or by making an inference. According to two independent raters, over half of the questions (20/28) on PAT-Revised Form A, required the making of an inference. The majority of these, as with PAT-Revised Form B, were of the coherence type. There were an equal number of questions which relied on globally, as opposed to locally, obtained information.

The main difference between the distribution of question types in the oral comprehension test compared to the reading comprehension test, was that the oral comprehension test had a greater proportion of questions that required making an inference (71% of the total as compared to 44%). However, the reading comprehension test, PAT-Revised Form B, has a greater proportion of questions which relied on the integration of globally presented information (70% as compared to 50% on PAT-Revised Form A). Both the oral and reading comprehension measure had more questions relying on a coherence type inference than on an elaborative type inference. In both tests the proportion of questions requiring a coherence type inference was 70%.

No statistics were available on the reliability and validity of this test of oral comprehension since it was adapted from the alternative form of PAT Reading Comprehension 3-5 (form A). However, the internal consistency of the test, which is reported in Section 4.1.2, was found to be satisfactory.

Receptive Vocabulary

The Peabody Picture Vocabulary Test, Third Edition (PPVT-III) is described as measure of a person's receptive (or hearing) vocabulary which shows the extent of vocabulary acquisition in standard English (Dunn & Dunn, 1997). It is an individually administered, un-timed, norm-referenced test available in two parallel forms (form A was used in this research study). The test was developed in the United

States and is designed for persons 2 $^{1}/_{2}$ to 90+ years. The PPVT-III was standardized nationally in the United States on a sample of 2,725 persons aged 2.5 to 90+ years of age. The sample included 2000 children and adolescents and 725 persons over the age of 19. It is used widely in Australia in both the clinical and research contexts.

The PPVT-III was administered according to the standardized instructions in the test manual (Dunn & Dunn, 1997). Each form contains four training items and 204 test items. Each item consists of four black and white illustrations. The test taker selects the picture that best represents the meaning of a stimulus word presented orally. The test is individually administered and testing time averages approximately 11 to 12 minutes. The words are of different types including nouns, adjectives and verbs and cover twenty content areas including animals, body parts, clothing, emotions, facial expressions and foods. The starting point of the test varies according to age, with older subjects commencing at a later point. A basal point of entry is established after one or no errors in a set of 12 responses and a ceiling is established after eight or more errors in a set of 12 responses comprising a set.

The reliability and validity of the PPVT-III are high (Dunn & Dunn, 1997). Four types of reliability were computed for the PPVT-III. Split-half internal consistency for 25 age groups range from .89 to .97 for form IIIA and from .86-.96 for form IIIB. Alternate-form reliability computed from standard scores range from .88 to .96 with a median value of .94 and the co-efficients computed from raw scores range from .89 to

.99 with a median value of .95. Test-retest reliabilities for 226 randomly selected individuals in four age groups range from .85-.90 for form IIIA and from .87 to .91 for form IIIB. Mean standard errors of measurement range from 3.0 to 5.3 with the average standard error of measurement for standard scores across ages being 3.7.

The PPVT-III demonstrates good concurrent validity and correlates well with other measures of vocabulary (e.g., the correlation with the vocabulary test in the Kaufman Brief Intelligence Test was .82) and moderately well with tests of verbal ability (e.g., between .63 to .83 with the subtests on the Oral and Written Language Scales (OWLS)) (Dunn & Dunn, 1997). Content validity was established by drawing items from a pool of standard English words that could be depicted by an illustration and selecting items representative of 20 common content areas. The construct validity of the test was established by showing greater increases in raw scores in the younger age groups with more gradual changes in the later years.

Receptive Grammar and Syntax

The TROG is an individually administered un-timed British test designed to assess understanding of grammatical contrasts in English (Bishop, 1983). The TROG was originally designed as a research tool for use in assessing language comprehension in children with developmental language disorders but a standardized final version of the TROG was devised in 1981 which was suitable for clinical use. It was standardized on over 2,000 British children aged from 4 to 12 years who were representative of the

British population. There are no Australian norms for the TROG and it was decided to use raw scores rather than standardized scores for this measure.

The test was administered according to the standardized instructions in the test manual (Bishop, 1983). The test comprises a book containing four coloured pictures on each of the pages. Children were told to select the picture corresponding to a phrase or sentence spoken by the examiner from one of four coloured pictures. Items are divided into 20 blocks with 4 items in each. Each block tests understanding of a specific type of contrast (e.g., reversible passives such as, “the girl is chased by the horse”, and embedded sentences such as, “the book the pencil is on is red”). The blocks are arranged in order of increasing difficulty and the starting point is graded according to age with older children starting on later blocks. The ceiling is reached after the failure of five consecutive blocks and testing is discontinued.

The reliability of the TROG is high. Split half reliability co-efficients, based on total scores on odd and even blocks, range between .65 and .85 across age groups. The concurrent validity of the TROG is not reported. However, Bishop (1983) reports that an earlier version of the TROG successfully discriminated language disordered children who had been diagnosed with expressive grammatical problems from children who had not. These children also performed poorly on the PPVT but their performance on the TROG was disproportionately poor.

3.2.5 Memory

There were eight memory measures. These included measures of verbal and visuospatial STM, measures of verbal and visuospatial WM, a measure of the ability to inhibit irrelevant information from WM and a measure of verbal learning and retrieval.

Verbal STM

Two measures of short-term verbal memory were used: forward digit span and the number of words recalled on the first learning trial of the Rey Auditory Verbal Learning Test (RAVLT).

Forward Digit Span

Forward digit span is a subtest of the Wechsler Intelligence Scale for Children (WISC-III) and is the most commonly used measure of short-term verbal recall in children (Wechsler, 1996). In the test, the examiner reads aloud a set of random number sequences at the rate of one per second and the examinee is required to immediately repeat back the same sequence of digits. Children were instructed as follows:

> *I am going to say some numbers to you. Listen carefully, and when I have finished, say them right back to me in the same order as you heard them.*

In the current study there was an initial trial of two number sequences comprising two digit sequences followed by eight pairs of number sequences, ranging from two to nine digits long. Testing was discontinued when the examinee has given incorrect responses for two number sequences with the same number of digits.

RAVLT (1st Trial)

The other measure of verbal STM was the number of words recalled on the first trial of the Rey Auditory Verbal Learning Test (RAVLT) which is a 15 item word list (Spreen & Strauss, 1998). The original French version was developed by Andre Rey (1958) and Taylor (1959) and Lezak (1995) later altered the test and adapted it for use with English-speaking populations.

The RAVLT can be used with either adult or child populations and is widely used in Australia. The test was normed with a sample of 376 children aged between 7 to 14 years selected to be representative of the Melbourne school population (Anderson, Lajoie, & Bell, 1995). There are also several non-Australian sets of norms for the RAVLT for both child and adult populations (Spreen & Strauss, 1998). A summary of the current literature on the RAVLT and norms are also provided by Schmidt (1996).

The instructions for the administration of the first trial of the RAVLT were as follows:

> *I am going to read a long list of words, too many to remember all at once. Listen carefully, because when I have finished I want you to tell me all the words that you remember. You don't need to say them in the same order as I do.*

The words were read at a rate of one per second and the examiner checked off the recalled words. No feedback was given regarding the correct responses or errors.

The reliability and validity of the RAVLT are discussed below in the section on verbal learning and retrieval.

Visuospatial STM

The Corsi block tapping task (Corsi, 1973) has been widely used as a test of short-term visuospatial memory in both adult and child populations (Berch et al., 1998). The task is viewed as a non-verbal equivalent of digit span. Variants of the Corsi are found in the adult Weschler Intelligence and Memory Scales. The non-computerised form of the test comprises 9 blocks numbered from 1-9 (with numbers facing the examiner) arranged on a board in a prescribed configuration.

The Corsi task has also been adapted to computerized formats. A computerized version of the task was used in the current study in which nine blue blocks lit up in red, one after the other, at a rate of one block per 1.5 s on a touch-screen computer. The blocks were arranged on the screen so as to replicate approximately the position of the blocks in the original Corsi apparatus (Corsi, 1973). The objective was to touch the blocks on the screen in the same order that they lit up. Prior to commencing the task there were six practice trials consisting of two and three block sequences. In the main task the number of blocks lighting up increased in a graded fashion from two to nine with two sequences at each level. Responses were recorded on the computer. There were two different trials for each number of illuminated blocks and testing was automatically halted at two incorrect responses for both trials on the same number of illuminated blocks. If there were no incorrect responses, the computer program terminates at the end of the second nine block sequence and a congratulatory message appears on the screen.

Children were instructed as follows:

> *In this game there are nine blue blocks on the screen. Some blocks will light up in red one after the other. Your job is to wait until the blocks stop lighting up then to touch the blocks that have lit up in the same order. In the first two, two blocks will light up, in the second two three blocks will light up and so on, to a maximum of 9 blocks. There are two practices to begin with to show you what to do.*

The Corsi block test is regarded as a valid measure of visuospatial STM. Corsi demonstrated a double dissociation between performance on digit span and performance on the Corsi block-tapping task in left and right unilateral brain resection groups. Individuals who had undergone left temporal lobe resection had deficits on digit span tasks while those with right medial temporal resection had deficits on the Corsi task. This finding established the Corsi procedure as one of the pre-eminent measures of spatial memory and the test was included as part of the Wechsler Memory battery.

Verbal WM

There were two measures of verbal WM. These were backward digit span (Wechsler, 1996) and a number span task based on one developed by Yuill, Oakhill and Parkin (1989).

Backward Digit Span

Backward digit span is the most commonly used measure of verbal WM. The test used was based on the backward digit span subtest in the Wechsler Intelligence Scale for Children (WISC-III) (Wechsler, 1996). A sequence of digits was read aloud by the examiner at a rate of one per second and the examinee was required to repeat the sequence of digits in exactly the reverse order. Children were instructed as follows:

> *I am going to say some numbers to you. Listen carefully, and when I have finished, say them right back to me in the reverse (that's backward) order to how you heard them.*

There was an initial trial of two number sequences comprising two digit sequences followed by seven pairs of number sequences, ranging from two to eight digits long. Testing was discontinued when the examinee had given incorrect responses for two number sequences with the same number of digits.

Triplet Number Task

The triplet number task was based on one developed by Yuill, Oakhill and Parkin (1989) as a verbal equivalent to Daneman and Carpenter's (1980) sentence span task, but one that was relatively independent of language skills. That is, the triplet number span task consists of numeric rather than word stimuli.

In the current study the task was presented on computer. A set of three numbers was presented on a computer screen in a large font and the objective was to read all three numbers aloud and to remember the final digit from each set in order of set presentation. Responses were given orally. For example, with the number sets 923 and 856, the numbers to be recalled are 3 and 6. The memory load was varied by increasing the number of sets of digits which increased the number of final digits to be recalled. The number of digits in each set was always three. Children were instructed as follows:

> *In this game a set of three numbers are going to appear on the screen at the same time. I want you to read out the three numbers in the set aloud to me. Your job is*

to remember the last number (that's the third number) from each set in the order that they came up. So, say the numbers 3,8, and 9 came up, then the numbers 2,5, and 7, the correct answer is 9, 7. Do you understand? Let's have a practice.

The test commenced with two practice trials comprising two number sets in each and then the number of sets increased in a graded fashion from two to seven. There were two different trials for each number of sets and testing was halted at two incorrect responses for both trials on the same number of sets.

Visuospatial WM

The visuospatial WM task, the Triplet block task, was devised as the visuospatial equivalent of the Number Span task. As noted in Section 2.4.6, the backward version of the Corsi block-tapping task was not used because of concerns about its validity (Berch et al., 1998; Gathercole, 1998). In the Triplet span task, nine blue blocks were presented on a touch-screen computer (as in the Corsi task) and sequences of three blocks lit up, one after another at a rate of one block per 2 s. The objective was to touch each block as it lit up on the screen and to remember the position of the third block from each triplet block sequence in the same order that the sequences appeared. Responses were recorded by touching the recalled blocks on the computer touch screen. Children were instructed as follows:

In this game there are nine blue blocks on the screen. Three blocks will light up in red one after the other. Your job is to touch the blocks as they light up and to remember the position of the last (the third block) that lit up. When it's time for you to give the answer you have to touch the third block that came up from each set in the same order. So, if three blocks lit up three times you would remember the third block from each, so that would be three blocks. In the first two, two sets of triplet block sequences will light up, in the second two, three sets will light up and so on, to a maximum of seven sequences. Let's have a practice.

There were six practice trials consisting of two and three triplet block sequences. In the main task the number of triplet block sequences increased in a graded fashion from two to seven triplets. There were two different trials for each number of triplet sequences and testing was automatically halted at two incorrect responses for both trials on the same number of triplet block sequences. If there were no incorrect responses, the computer program terminated after the second seven triplet sequence and a congratulatory message appeared on the screen.

Inhibition of irrelevant information: RAVLT interference

The ability to inhibit irrelevant information was measured using the RAVLT (Spreen & Strauss, 1998). Interference was measured in terms of the number of irrelevant words (intrusions) over the five learning trials and the delay trial. The RAVLT is described in detail below in the section on verbal learning and retrieval.

Verbal Episodic Long Term Learning and Retrieval

A measure of verbal episodic learning and retrieval was taken from the RAVLT (Spreen & Strauss, 1998). The measure was the total number of words recalled on the delay trial which was conducted thirty minutes after the administration of the five initial learning trials, without further exposure to the words.

The 15 words are read aloud with a one second interval between each word for five consecutive trials, each trial followed by a free-recall test. For each trial the examiner checks off the recalled words and makes a note of any intrusions. The order of presentation of the words is fixed across trials but the words can be recalled in any order. The total number of words recalled for each trial is noted. Following the first trial, the examiner gives the following instructions:

> *Now, I'm going to read the same words again and when I stop I want you to tell me all over again what you remember, even the words you said the last time.*

The list is read in the same manner for trials 2 to 5 using the same instructions. The examiner does not re-read the list of words for the delay trial, which is administered 30 minutes after trial 5. In the delay trial, children are asked to recall as many of the words, that have been read to them on five previous occasions, as possible.

The RAVLT has been found to have a STM component (Trial 1) and a retrieval component, the ability to retrieve material once learned (delay trial) (Spreen & Strauss, 1998). Scores on the RAVLT are higher than those on the California Verbal Learning Test (CVLT) but the difference is not clinically significant and appears to be due to the longer CVLT list (Crossen & Wiens, 1994). Factor analytic studies show that the RAVLT loads primarily with other tests of verbal memory such as those on the Wechsler Memory Scale and correlates significantly with other learning measures, in the range of .50 to .65 (Lezac, 1995; Ryan, Rosenberg & Mittenberg, 1984). The RAVLT is sensitive to verbal memory deficits in a variety of patient groups including those with Alzheimer's disease or a closed head injury.

3.3 Procedure

Approval was first obtained from the Faculty Ethics Committee at La Trobe University and subsequently from the Victorian Department of Education, Employment and Training (Office of Schools) to conduct the research study in government primary schools. Consent was then obtained from the principals of two Melbourne primary schools to conduct the research in their schools. Information about the study was placed in the school weekly newsletters and consent forms were sent home with all children in grades 3, 4 and 5, together with a letter to parents giving full details of the study. Parents were also asked to complete a consent form for the release of their children's results on the AIM. The AIM is administered to all children in Victorian primary schools in grades 3 and 5 only.

Children whose parents had returned the consent forms to authorise their participation in the study took part in three group sessions of approximately 40 minutes, 30 minutes and 25 minutes duration with from 8 to 10 children in each group session. Children also each took part in an individual session of approximately a one hour duration. The group sessions were conducted over six days of a two week period in each school. Children took part in no more than one session per day. Most of the children completed all of the group sessions prior to the individual session except for a few children who were absent for some of the group tests. Additional group sessions were conducted at the end of the individual testing phase for children who had missed one or more of the group sessions.

In the group sessions, children completed PAT Reading-Revised Form B (the measure of reading comprehension) in one session of 40 minutes duration, the oral presentation measure in another session of approximately 30 minutes and the Raven's Standard Progress Matrices together with the Exposure to Print measure in another session of approximately 25 minutes duration. The reading comprehension measure and the Raven's Standard Progressive Matrices were timed tests and children were allowed 40 minutes to complete the reading comprehension measure and 20 minutes to complete the Raven's, as instructed in the Test Manuals.

The order of the tests (i.e. the three test sessions) was dictated by the school timetable and the amount of time classes had available. The order of presentation of the comprehension tasks was balanced, with approximately half of the children completing the reading comprehension test in their first group session and half completing the oral comprehension measure in their first group session. Most children completed the Raven's Standard Progressive Matrices and the TRT in the third and final group session. Testing took place in unoccupied classrooms.

In the one-hour individual session, each child was tested alone in a quiet area of the school. The order of the tests was as follows: the RAVLT, Number Span Task, Forward Digit Span, Backward Digit Span, PPVT-III, Martin and Pratt Nonword Reading Test, Word Identification (Woodcock), Irregular Word List, Neale Reading Passage, the TROG, the delay measure on the RAVLT and finally the Corsi block task and the Triplet span task. The order of the Corsi block task and the Triplet span task was counterbalanced since familiarity with the computer equipment is likely to lead to practice effects. The individual testing took place on three days a week over a period of approximately eight weeks in each school.

CHAPTER 4. RESULTS

This chapter contains descriptive data, correlations, partial correlations controlling for age and general intellectual ability and the results of a series of hierarchical regression analyses. The hierarchical regressions were undertaken to identify the strongest set of predictors from the 1) word reading, 2) language and 3) memory variables with a view to building a model of reading comprehension. The strength of this model is subsequently compared with that of both additive and multiplicative variants of traditional models such as the *simple view.*

4.1 Descriptive Statistics

4.1.1 Scoring

Raw scores were calculated for the standardized tests as set out in the manuals. A derived score was calculated for the TRT using the method employed by Cunningham and Stanovich (1990). For each participant on the TRT the number of correct targets was identified (M =9.1, SD =3.2) and also the number of foils checked (M = 4.3, SD = 4.0). The range was 2-20 checked on the titles and 0-20 on the foils. The derived score, which takes into account possible differential thresholds for guessing, was based on the high threshold correction for guessing targets (i.e., real titles) in the presence of foils; namely, probability of a correct detection = [P(target) - P(foil)] / [1- P(foil)]. The number of errors on the Neale was calculated as a percentage of the number of words in the passage since the three grades read passages of different lengths. That is, grade 3 Neale errors score was calculated as a percentage of 73 words, grade 4 as a percentage of 96 words and grade 5 as a percentage of 117 words. Reading speed was calculated as the number of words read per minute on the reading passage from the Neale (1999). That is, the number of words in the reading passage was divided by the time taken in seconds to read it and multiplied by 60. The scores on span tasks (forward digit span, backward digit span, triplet number span, the Corsi task and triplet block task) were calculated from the total number of correct trials achieved. Three scores were derived from the RAVLT: a measure of short-term verbal memory, which was the total number of words recalled on the first trial of the RAVLT; a measure of WM inhibition, which was the total number of irrelevant words recalled on the five initial trials of the RAVLT; and the delay trial, and a measure of verbal learning and retrieval which was the total number of words recalled on the delay trial of the RAVLT.

4.1.2 Internal consistency

The internal consistencies of the reading comprehension measure (PAT Reading-Revised Form B) the oral comprehension measure (PAT Reading-Revised Form A), irregular word reading, the TRT and the memory span tasks were assessed using Cronbach α. The internal consistencies of PAT B (α =.86) and the irregular word reading test (α =.94) were high. The internal consistencies of PAT-A (α =.76) and the TRT (α =.81) were also satisfactory. The internal consistencies of forward digit span, backward digit span, the triplet number span task, the Corsi block task and the triplet block span task were acceptable at .82, .74, .69, .75 and .75 respectively (after excluding items with <5% or >95% successes). All the internal consistencies, with the exception of the triplet number task, which was .69, were above the minimum recommended level of .7 and were therefore satisfactory (Nunnally, 1978).

4.1.3 Summary Statistics

The means and standard deviations for each test are presented in Table 4.1. Inspection of the means, standard deviations and actual range of scores in comparison with the possible range reveals there was a sufficient spread of scores with no obvious ceiling or floor effects with the exception of the TROG.

The spread of scores on the TROG are negatively skewed. The range of scores was consistent with those documented in the norms for this test in this age group. For example, the norms show that the 50^{th} percentile for 10 to 12 year-olds is 18 blocks (out of a possible 20 blocks), compared to a 50^{th} percentile of 17 blocks for the current sample. In the current sample approximately 11% of participants correctly answered at or below 14 blocks, 54% answered at or below 17 blocks, 78% at or below 18 blocks and 97.8% of participants at or below 19 blocks. Nevertheless, this skewed distribution of TROG scores may attenuate the magnitude of the relationship with reading comprehension and other measures in correlational and regression analyses.

Table 4.1

Mean, Standard Deviation, Range, and Possible Range of Measures of Reading Comprehension, Word Reading, Memory, and Language

Measures	*n*	*M*	*SD*	Range	Possible Range
Reading Comprehension					
PAT B	180	26.79	6.86	8 - 39	0 - 39
Word Reading					
Irregular words	180	20.53	8.73	1 - 41	0 - 44
Nonwords	180	36.12	11.45	3 - 54	0 - 54
Neale Errors	177	7.12	8.32	0 - 45	0 - 100
Neale Speed	177	88.52	34.53	21 - 195	
TRT	180	0.27	0.25	-1.00 - 0.75	
Language					
PAT A	180	18.78	4.43	6 - 28	0 - 28
PPVT-III	180	133.74	18.41	87 - 174	0 - 204
TROG	180	16.93	1.88	10 - 20	0 - 20
Memory					
RAVLT Delay	179	8.99	2.57	0 - 15	0 - 15
RAVLT Int.	179	1.43	2.59	0 - 20	
RAVLT Trial 1	180	5.06	1.73	0 - 11	0 - 15
Forward Digit	179	6.47	1.68	3 - 11	0 - 16
Backward Digit	179	4.82	1.60	2 - 10	0 - 14
Triplet Number	180	3.57	1.50	0 - 8	0 - 12
Corsi	178	5.84	1.82	1 - 10	0 - 16
Triplet Block	179	4.64	2.29	0 - 10	0 - 12

4.2 Distribution Of Reading Comprehension Skills

The aim of the current study was to formulate a model of reading comprehension. It is therefore important that the sample contains a normal range of reading comprehension skills, with sufficient numbers at the lower and higher ends of the continuum.

The distribution of reading comprehension skills is negatively skewed, skewness = -.515, which indicates that there is a clustering of scores towards the high end. In order to determine whether there was an adequate range of reading comprehension ability within the sample, the distribution of raw scores on the PAT Reading Comprehension Test was further examined. The distribution of scores, is depicted in Figure 4.1. Sixteen percent of the sample scored 20 or below and 32% scored 30 or above. The majority of scores (52%) fell within the 21-30 range. The negative skew in the distribution of scores in the grade levels tested in the current sample is largely consistent with the national Australian norms for this test provided by the Australian Council for Educational Research (ACER-Press, 2000). The scores of the current sample are however slightly higher than those documented in the norms.

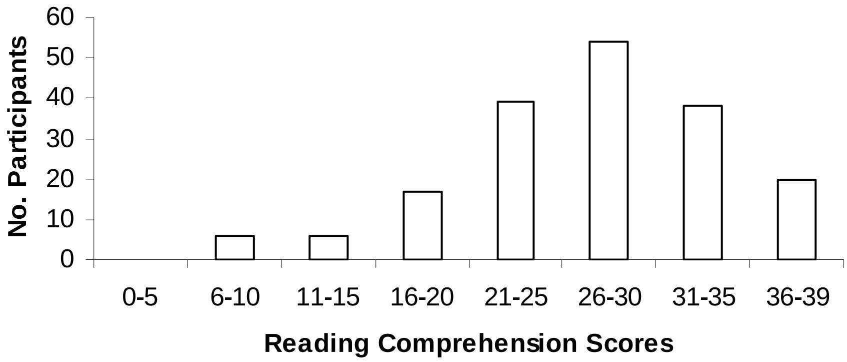

Figure 4.1 *Distribution of Raw Scores on PAT Reading Comprehension*

4.3 Distribution of Word Reading Skills

Adequate word reading skills are a prerequisite of reading comprehension (Perfetti, 1985). Although word reading skills will be controlled for in the subsequent statistical analyses investigating the relationship between reading comprehension and other predictor variables, an over-representation of children with poor word reading skills in the sample could potentially confound poor reading comprehension with inadequate word reading skills.

The discrepancy between chronological age and word reading age on the Woodcock word identification subtest in the sample is shown in Figure 4.2. Sixty-one percent of the sample had a reading age at or above their chronological age and 36 percent of the

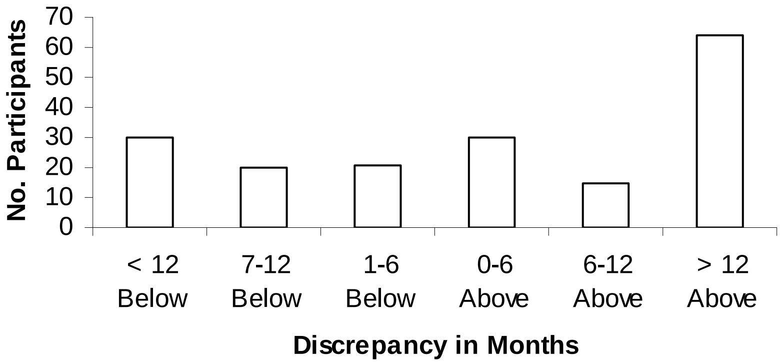

Figure 4.2. *Discrepancy Between Reading Age and Chronological Age in the Sample*

sample had a reading age 12 months or more above their chronological age. Only 17% of the sample had a reading age 12 months or more below their chronological age. This confirmed that poor word readers were not over-represented in the sample.

4.4 Correlational Analyses

Table 4.2 shows the correlations between reading comprehension and measures of (a) word reading, (b) memory and (c) language skills. PAT B reading comprehension correlated strongly with measures of word reading and, to a lesser extent, with measures of language skill. Of the word reading variables, reading comprehension correlated most strongly with irregular word reading, r =.73, p<.01, and, of the language variables, with oral comprehension (PAT A), r =.69, p<.01. Correlations between the PAT and the memory measures were lower than with the word reading and the language variables but

Table 4.2

Pearson's Correlation Coefficients between Reading Comprehension (PAT B) and measures of (a) Word Reading b) Memory and c) Language

(a) Word Reading	**n**	**2**	**3**	**4**	**5**	**6**
1. PAT B	180	.73**	.52**	-.51**	.54**	.41**
2. Irregular Words	180		.71**	-.64**	.69**	.36**
3. Nonwords	180			-.72**	.51**	.22**
4. Neale Errors	177				-.59**	-.28**
5. Neale Speed	177					.23**
6. TRT	180					

(b) Language	**n**	**2**	**3**	**4**
1. PAT B	180	.69**	.67**	.57**
2. PAT A	180		.61**	.47**
3. PPVT-III	180			.53**
4. TROG	180			

(c) Memory	**n**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1 PAT B	180	.31**	-.09	.22**	.33**	.37**	.32**	.36**	.29**
2. RAVLT Delay	179		-.17*	.31**	.04	.32**	.17*	.12	.15*
3. RAVLT Int.	179			-.11	-.05	-.20*	-.13	-.05	-.09
4. RAVLT Trial 1	180				.16*	.22**	.12	.09	.18*
5. Forward Digit	179					.42**	.22**	.17*	.15*
6. Backward Digit	179						.38**	.20*	.31**
7. Triplet Number	180							.30**	.31**
8. Corsi	178								.31**
9. Triplet Block	179								

**p* < .05; ** *p* < .01.

with one exception, were still significant. RAVLT intrusions, the measure of WM inhibition, was the only memory measure that was not significantly correlated with reading comprehension.

As would be expected, the inter-task correlations amongst the word reading measures were high. There was a high correlation between irregular word and nonword reading, r =.71, p<.01. The TRT was significantly correlated with all the word reading variables but the strongest correlation was with irregular word reading, r =-.36, p<.01.

The inter-task correlations between the language measures were reasonably high. Oral comprehension had a stronger relationship with PPVT-III, r =.61, p<.01, than with the TROG, r =.47, p<.01. The inter-task correlations amongst the memory measures were generally not as high. The highest inter-task correlation was between backward digit span and forward digit span, r =.42, p<.01. The triplet number span task, which was presented visually on a computer screen, like the two visuospatial tasks, was just as highly correlated with the Corsi and the triplet block task as they were with one another; triplet number span and the Corsi, r =.30 , p<.01; triplet number span and the triplet Block task; r =.31 , p<.01. The relationship between the RAVLT delay measure and the majority of the STM measures was very weak.

4.5 Controlling for Age and Intellectual Ability

4.5.1 Variance Accounted for by Age and General Intellectual Ability

Reading comprehension scores were expected to be significantly correlated with age and general intellectual ability. In order to determine whether it was necessary to control for age and general intellectual ability when investigating the relationship between reading comprehension and the other variables, a further correlational analysis was conducted to determine the relationship between reading comprehension, age and general intellectual ability. The correlation between reading comprehension and age was $r = .24$, $p < .05$, and the correlation between reading comprehension and general intellectual ability on the Ravens Progressive Matrices was $r = .30$, $p < .01$. That is, reading comprehension was significantly correlated with both age and general intellectual ability.

4.5.2 Partial Correlations

The correlations between the main measures were re-run, controlling for age and general intellectual ability. The partial correlations are presented in Table 4.3.

The partial correlations show that, after controlling for age and general intellectual ability, the relationships between the variables are, for the most part, slightly attenuated. Irregular word reading remained the most strongly associated with reading

Table 4.3
Partial Correlation coefficients between Reading Comprehension (PAT B) and the Predictor Variables, after Controlling for Age and General Intellectual Ability

(a) Word Reading	**n**	**2**	**3**	**4**	**5**	**6**
1. PAT B	180	.67**	.48**	-.51**	.55**	.37**
2. Irregular words	180		.70**	-.67**	.72**	.31**
3. Nonwords	180			-.72**	.50**	.18*
4. Neale Errors	177				-.58**	-.26**
5. Neale Speed	177					.21*
6. TRT	180					

(b) Language	**n**	**2**	**3**	**4**
1. PAT B	180	.61**	.62**	.50**
2. PAT A	180		.54**	.38**
3. PPVT-III	180			.47**
4. TROG	180			

(c) Memory	**n**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1 PAT B	180	.21*	-.07	.16*	.30**	.31**	.24**	.28**	.20*
2. RAVLT Delay	179		-.16*	.30**	.01	.28**	.09	.04	.06
3. RAVLT Int.	179			-.11	-.04	-.19*	-.11	-.04	-.07
4. RAVLT Trial 1	180				.12	.18*	.09	.05	.16*
5. Forward Digit	179					.40**	.21*	.15*	.14
6. Backward Digit	179						.35**	.15*	.28**
7. Triplet Number	180							.25**	.25**
8. Corsi	178								.25**
9. Triplet Block	179								

* $p < .05$; ** $p < .01$

comprehension, r =.67, p<.01. As was the case prior to controlling for age and general intellectual ability, the number of intrusions on the RAVLT is the only variable that does not have a significant relationship with reading comprehension. The pattern of the relationships between reading comprehension and the memory variables have changed slightly. After controlling for age and general intellectual ability, forward, r =.30, p<.01 and backward digit span, r =.31, p<.01, have the strongest relationship with reading comprehension. This is in contrast to prior to controlling for age and general intellectual ability, when backward digit span, r =.37, p<.01 and the Corsi task, r =.36, p<.01 were found to have the strongest relationship with reading comprehension.

4.6 Selecting The Strongest Predictors From Each Variable Type

Three exploratory regression analyses were conducted to select the strongest predictor variables from 1) the word reading, 2) the memory and 3) the language variables. Age and general intellectual ability were entered first in all three analyses, followed by a forward stepwise procedure to identify the strongest predictor variables. An SPSS FORWARD procedure was used to select predictors in step 2 because the SPSS stepwise procedure might have removed previously entered covariates (i.e., Age and IQ) from the equation.

4.6.1 Word Reading Variables

An hierarchical regression was conducted predicting reading comprehension with irregular word reading, nonword reading, Neale errors, Neale speed and the TRT entered together in the second step after the effects of age and general intellectual ability had been accounted for in step 1. The results are presented in Table 4.4.

Table 4.4

Hierarchical Regression Predicting Reading Comprehension with Irregular Word Reading, Nonword Reading, Neale Errors, Neale Speed and the TRT Entered In The Second Step after Controlling for Age and General Intellectual Ability (N =177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
†2	Irregular Words	0.48	0.05	0.60	.52**	.36**
	TRT	4.41	1.50	0.16	.15**	.02**

* $p < .05$; ** $p < .01$

† SPSS forward procedure

Of all the word reading variables, only irregular word reading and the TRT made a significant non-redundant contribution to reading comprehension. Irregular word reading was the much stronger predictor of the two and contributed 27% (*sr* =.52) of the variance in reading comprehension, whilst the TRT contributed an additional 2%

(*sr* =.15) of the variance. Tabachnick and Fidell (1996) note that squared semi-partial correlation (sr^2) is the most useful measure of the importance of a predictor variable since it expresses the unique contribution of the predictor variable to the total variance of the dependent variable.

4.6.2 Language Variables

An hierarchical regression was conducted predicting reading comprehension with PPVT-III, oral comprehension (PAT A) and the TROG entered together in the second step after controlling for age and general intellectual ability in step 1. The results are presented in Table 4.5.

Of the language variables, all three were selected as significant and non-redundant predictors of reading comprehension. PPVT-III accounted for 5% (*sr* =.23) of the variance, oral comprehension accounted for a further 7% (*sr* =.26), and TROG accounted for a further 3% (*sr* =.17) of the variance in reading comprehension.

Table 4.5

Hierarchical Regression Predicting Reading Comprehension with PPVT-III, Oral Comprehension and the TROG Entered in the Second Step after Controlling for Age and General Intellectual Ability (N =177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
†2	PPVT-III	0.12	0.02	0.32	.23**	.31**
	PAT A	0.55	0.10	0.35	.26**	.09**
	TROG	0.75	0.21	0.21	.17**	.03**

* $p < .05$; ** $p < .01$

† SPSS forward procedure

4.6.3 Memory Variables

An hierarchical regression was conducted predicting reading comprehension with RAVLT Delay, RAVLT intrusions, 1st trial on the RAVLT, forward digit span, backward digit span, triplet number span, Corsi, and triplet block span entered together in the second step after controlling for age and general intellectual ability in step 1. The results are presented in Table 4.6.

Table 4.6.

Hierarchical Regression Predicting Reading Comprehension with RAVLT Delay, RAVLT Intrusions, 1st Trial on the RAVLT, Forward Digit Span, Backward Digit Span, Triplet Number Span, Corsi, and Triplet Block Span Entered in the Second Step after Controlling for Age and General Intellectual Ability (N =177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
†2	Backward Digit Span	0.57	0.31	0.13	.11	.08**
	Corsi	0.77	0.24	0.21	.19**	.05**
	Forward Digit Span	0.79	0.28	0.19	.17*	.03*
	RAVLT Delay	0.39	0.18	0.15	.13*	.02*

* $p < .05$; ** $p < .01$

† SPSS forward procedure

Four variables were found to make significant non-redundant contributions to reading comprehension. These were backward digit span, which accounted for 1% (*sr* =.11) of the variance, Corsi, which accounted for a further 4% (*sr* =.19) of the variance, forward digit span, which accounted for a further 3% (*sr* =.17) of the variance, and RAVLT delay, which accounted for a further 2% (*sr* =.13) of the variance in reading comprehension.

4.7 Building a Model

From the previous analyses, irregular word reading and the TRT were selected as the significant independent predictors of reading comprehension from the word reading variables, PPVT-III, oral comprehension (PAT A) and the TROG from the language variables and backward digit span, Corsi, forward digit span and RAVLT delay from the memory variables. Prior to carrying out regression analyses using these variables, correlational analyses were conducted to ensure that there was no problem of collinearity. The correlations are presented in Table 4.7 below. None of the correlations were above 0.90, at which point Tabachnick and Fidell (1996) state that collinearity becomes a serious issue.

Table 4.7

Pearson's Correlation Coefficients between Variables Selected as Making an Independent Contribution to Reading Comprehension

		n	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Irregular words	180	.36**	.58**	.47**	.48**	.47**	.27**	.37**	.28**
2.	TRT	180		.38**	.27**	.19*	.17*	.05	.16*	.06
3.	PPVT	180			.61**	.53**	.24**	.29**	.31**	.13
4.	PAT A	180				.47**	.28**	.35**	.29**	.20**
5.	TROG	180					.32**	.25**	.30**	.10
6.	Backward Digit	179	.					.20**	.42**	.32**
7.	Corsi	178							.17*	.12
8.	Forward Digit	178								.04
9.	RAVLT Delay	179								

$*p < .05$; $** p < .01$.

Two hierarchical regression analyses were conducted to determine the combination of these variables that best predicted reading comprehension. The word reading variables were entered before the memory and the language variables since word reading is viewed as a prerequisite for reading comprehension. As there is no theoretical basis to determine the order of entry of the memory and the language variables, the order of entry of these variables was reversed in the two analyses such that the language variables were entered before the memory variables in the first analysis and the memory variables before the language variables in the second analysis. The results of these analyses are presented in Table 4.8.

The memory variables do not make a significant contribution to reading comprehension when entered after the language variables, $F(4,165) = 1.983$, $p = .10$. Even when the memory variables are entered prior to the language variables they account for only 3% of the variance in reading comprehension, $F(4,168) = 3.802$, $p < .05$.

The language variables, on the other hand, account for 13% of the variance in reading comprehension, even when entered after the memory variables, $F(3,165) = 26.422$, $p < .01$. The semi-partial correlations show that although all of the language variables make an independent contribution to reading comprehension, oral comprehension (PAT A) makes by far the strongest independent contribution, contributing approximately 6% ($sr = .24$) of the variance.

Table 4.8

Hierarchical Regressions Predicting Reading Comprehension with Word Reading, Language and Memory Measures after Controlling for Age and General Intellectual Ability (N =177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
(a) Language measures entered before Memory measures						
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
2.	Irregular Words	0.48	0.05	0.60	.52**	
	TRT	4.51	1.47	0.16	.15**	.38**
3.	PPVT-III	0.05	0.02	0.13	.09*	
	PAT A	0.50	0.08	0.33	.24**	
	TROG	0.48	0.18	0.13	.11*	.15**
4.	Backward Digit Span	-0.16	0.21	-0.04	-.03	
	Corsi	0.24	0.16	0.06	.06	
	Forward Digit Span	0.04	0.19	0.01	.01	
	RAVLT Delay	0.29	0.12	0.11	.10*	.01
(b) Memory measures entered before Language measures						
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
2.	Irregular Words	0.48	0.05	0.60	.52**	
	TRT	4.51	1.47	0.16	.15**	.38**
3.	Backward Digit Span	-0.16	0.25	-.04	-.03	
	Corsi	0.60	0.19	0.16	.15**	
	Forward Digit Span	0.29	0.23	0.07	.06	
	RAVLT Delay	0.30	0.14	0.11	.09	.03*
4.	PPVT-III	0.05	0.02	0.12	.08*	
	PAT A	0.47	0.09	0.31	.22**	
	TROG	0.52	0.18	0.14	.11*	.13**

p < .05; ** p < .01

The RAVLT delay is the only memory variable to make an independent contribution to reading comprehension after the input of the language variables, contributing 1% (*sr* =.11) of the variance. Interestingly, neither backward (*sr* = -.03) nor forward digit span (*sr* =.06) make an independent contribution to reading comprehension even prior to the entry of the language variables. Of all the memory variables, the Corsi makes the largest independent contribution to reading comprehension prior to the entry of the language variables, contributing 2% (*sr* =.15) of the variance.

The linear model formulated, which includes the word reading, language and memory variables accounts for 53% of the variance in reading comprehension after controlling for age and general intellectual ability. The strength of the model formulated will be compared with that of the *simple view* in Section 4.9.

4.8 Predictors of Irregular Word Reading

Irregular word reading is the strongest predictor of reading comprehension in the model formulated. As discussed in the Introduction (see Section 2.2.1.1), irregular word ability is dependent on other skills and there was expected to be substantial over-lapping variance between irregular word reading and many of the other variables.

The results of the previous analyses support this stance. That is, prior to the entry of irregular word reading and the TRT, both the language and the memory variables accounted for considerably more variance in reading comprehension than after the entry of these variables. Irregular word reading is a much stronger predictor of reading comprehension than the TRT indicating that irregular word reading has a strong relationship with both the language and the memory variables.

Irregular word reading also has a strong relationship with the other word reading variables. Both nonword reading and reading speed were significantly correlated with reading comprehension prior to the entry of irregular word reading in a regression analysis. Also, the independent contribution of the TRT to reading comprehension, although significant, is much reduced, when the TRT is entered together with irregular word reading in a regression analysis.

An hierarchical regression analysis was conducted to investigate the strongest predictors of irregular word reading (see Table 4.9). Age and general intellectual ability were entered in the first step and together accounted for 17% of the variance in irregular word reading, $F(2,173) = 17.513$, $p < .01$. General intellectual ability was by far the stronger predictor of the two and accounted for 10% ($sr = .32$) of the variance in irregular word reading. The variables entered in the second step were selected on the basis that after the entry of irregular word reading (see Section 4.7), their relationship with reading comprehension were greatly attenuated compared to prior to the entry of irregular word reading (see Section 4.6).

Table 4.9

Hierarchical Regression Predicting Irregular Word Reading with Nonword Reading, Neale Speed, TRT, PPVT-III, TROG, Backward Digit Span, Forward Digit Span, RAVLT Delay Entered in the Second Step after Controlling for Age and General Intellectual Ability (N =177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
1.	Age	0.13	0.06	0.16	.15*	
	Ravens	0.35	0.08	0.34	.32**	.17**
2.	Nonwords	0.29	0.04	0.38	.30**	
	Neale Speed	0.09	0.01	0.34	.26**	
	TRT	2.45	1.43	0.07	.06	
	PPVT-III	0.09	0.03	0.19	.14**	
	TROG	0.18	0.21	0.04	.03	
	Backward Digit Span	0.56	0.25	0.10	.08*	
	Forward Digit Span	-0.08	0.23	-0.02	-.01	
	RAVLT Delay	0.12	0.14	0.03	.03	.61**

*$p < .05$; ** $p < .01$

The variables selected were nonword reading, reading speed, TRT, PPVT-III, TROG, backward digit span, forward digit span and RAVLT Delay and together these variables accounted for 61% of the variance in irregular word reading, $F(8,165) = 55.67$, $p<.01$. Of these, only nonword reading, reading speed, PPVT-III and backward digit span made independent contributions to irregular word reading. Nonword reading made the largest contribution, accounting for 9% (*sr* =.30) of the variance in irregular word reading.

4.9 Evaluation of Traditional Models Such As The *Simple View*

Two hierachical regression analyses were conducted in order to compare the predictive power of both additive and multiplicative variants of Gough and Tunmer's (1986) s*imple view*, in which reading comprehension is viewed in terms of the sum or the product of phonological recoding (nonword reading) and oral comprehension skills, with an additive model in which nonword reading (phonological recoding) is substituted with irregular word reading (orthographic processing).

4.9.1 Multiplicative versus Additive Variants of the *Simple View*

It is not clear from the literature whether an additive or multiplicative variant of the *simple view* best predicts reading comprehension. An hierarchical regression analysis was conducted to examine whether the multiplicative model (the product of phonological recoding (D) and oral comprehension skills (C)) adds to the prediction of reading comprehension (R) beyond the additive model (the sum of phonological recoding and oral comprehension skills). As discussed in Section 2.1.1.1, the linear expression of the multiplicative model is R = D + C + (D x C), since the intersection (D x C) is undefined without the prior entry of the individual terms D + C (Cohen & Cohen, 1983). Thus, D + C must be entered into the regression analysis prior to D x C. The result of this analysis is presented in Table 4.10.

The multiplicative combination of phonological recoding (nonword reading) and oral comprehension (PAT A) did not make a significant contribution to reading comprehension beyond the contribution of the additive combination, $F(1,174) = 0.06$, $p = .80$.

Table 4.10

Hierarchical Regressions Predicting Reading Comprehension with Nonword Reading and Oral comprehension as Predictor Variables (N = 177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
(a) Simple View: Additive Combination entered before Multiplicative Combination						
	Covariates					
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
2.	Additive Model					
	Nonwords	0.22	0.03	0.37	.35**	
	PAT A	0.86	0.08	0.55	.49**	.43**
3.	Multiplicative Model					
	Nonwords*PAT A	-0.002	0.01	-0.06	-.012	.00

* $p < .05$; ** $p < .01$

The additive combination accounted for 43% of the variance in reading comprehension after controlling for age and general intellectual ability, $F(2,175) = 98.31$, $p < .01$. Oral comprehension was a much stronger predictor of reading comprehension than nonword reading, accounting for 24% (*sr* =.49) of the variance in reading comprehension, while nonword reading accounted for only 12% (*sr* =.35).

4.9.2 Alternative Model

A further hierachical regression analysis was conducted to compare the predictive power of the *simple view* with a model in which phonological recoding is substituted with orthographic processing. The results of this analysis are presented in Table 4.11.

Table 4.11

Hierarchical Regression Predicting Reading Comprehension with Irregular Word Reading and Oral Comprehension as Predictor Variables (N = 177)

Step	*Predictors*	*B*	*SE B*	β	*sr*	ΔR^2
	Covariates					
1.	Age	0.08	0.05	0.12	.11	
	Ravens	0.32	0.06	0.39	.38**	.20**
	Additive Model					
2.	Irregular Words	0.40	0.04	0.51	.44**	
	PAT A	0.67	0.08	0.43	.36**	.49**
	Multiplicative Model					
3.	Irregular Words* PAT A	-0.01	0.01	-0.37	-.06	.00

* p < .05; ** p < .01

Together, the additive combination of irregular word reading and oral comprehension accounted for 49% of the variance in reading comprehension scores $F(2,175) = 139.04$, $p<.01$. The multiplicative combination of orthographic processing (irregular word reading) and oral comprehension (PAT A) did not make a significant contribution to reading comprehension beyond the contribution of the additive combination, $F(1,174) = 2.25$, $p=.14$. Irregular word reading accounted for 19% (*sr* =.44) of the variance in reading comprehension, while oral comprehension accounted for 13% (*sr* =.36). This finding was not unexpected since in Sections 4.6, 4.7, and 4.8, irregular word reading was found to account for all of the variance in reading comprehension contributed by nonword reading, reading speed and backward digit span (verbal WM). Irregular word reading was also strongly associated with PPVT-III (receptive vocabulary) and, although receptive vocabulary remained a significant predictor of reading comprehension after the contribution of irregular word reading had been accounted for, its contribution was greatly reduced.

4.10 Summary Of Results

The results show that traditional models of children's reading comprehension such as the *simple view,* which incorporate only phonological recoding skills and oral comprehension, did not fully account for children's reading comprehension in the middle to latter primary school years in the current sample. A multiplicative version of the *simple view* provided no additional predictive power beyond that of an additive version.

The variables selected for possible inclusion in the model of reading comprehension were identified as being important to reading comprehension in the child and adult literature. All of the variables selected, with the exception of one, from the word reading, language and memory variables, were significantly positively correlated with reading comprehension, even after controlling for age and general intellectual ability. The measure of WM inhibition, RAVLT intrusions, was the only measure that was not significantly correlated with reading comprehension in this analysis. Both the verbal and visuospatial memory tasks were significantly correlated with reading comprehension after controlling for age and general intellectual ability, with correlations of a similar magnitude. The correlations between reading comprehension and the memory measures were generally of a much lower magnitude however than those between reading comprehension and the word reading or the language variables.

From the word reading variables, irregular word reading and exposure to print were found to make separate independent contributions to reading comprehension. Irregular word reading was by far the stronger predictor of the two. It accounted for all the variance in reading comprehension contributed by both phonological recoding skills and reading speed. That is, neither phonological recoding skills nor reading speed made an independent contribution to reading comprehension beyond that of irregular word reading. From the language variables, all three variables made an independent contribution to reading comprehension after controlling for age and general intellectual ability, with oral comprehension making the strongest contribution.

From the memory variables, backward digit span, forward digit span, the Corsi and RAVLT delay were selected as the best combination of predictors of reading comprehension. The strongest predictor in this analysis was the Corsi task.

Language was found to be a much stronger predictor of reading comprehension than memory. After controlling for age, general intellectual ability and word reading skills, when the three sets of predictor variables were entered into an hierarchical regression analysis, the language variables were stronger predictors of reading comprehension than the memory variables. In fact, the contribution of the memory variables was not significant after the addition of the language variables. Even when the memory variables were entered prior to the language variables, the set of memory variables made a very small, albeit statistically significant, contribution to reading comprehension. Interestingly, the Corsi task was the only measure that made an independent contribution to reading comprehension in this analysis. The measure of long-term learning and retrieval on the RAVLT was the only memory measure to make an independent contribution to reading comprehension after controlling for the language variables. However, this contribution was very small.

The use of a varied selection of memory variables revealed some interesting findings. The intercorrelations between the tasks were not high and the tasks with verbal stimuli were generally just as highly correlated with the tasks with visuospatial stimuli as they were with the other verbal memory tasks. The exception to this was the digit span tasks, which were presented in an oral rather than a visual format. That is, the correlation between forward and backward digit span was the highest amongst the memory measures. The WM measures proved to be no more strongly correlated with reading comprehension than the other STM measures.

Of all the variables, orthographic processing (irregular word reading) correlated the most strongly with reading comprehension. Irregular word reading had a strong relationship with phonological recoding and reading speed and accounted for all the variance that these two variables contributed to reading comprehension. It had been speculated that orthographic processing would be strongly associated with both receptive vocabulary and exposure to print. The correlations showed that irregular word reading was more strongly associated with the TRT than was nonword reading. It was found however, that although receptive vocabulary was an independent predictor of irregular word reading, the TRT was not. The findings show that orthographic processing (irregular word reading) incorporates variance from phonological recoding skills, reading speed, receptive vocabulary and verbal WM (backward digit span).

Finally, the additive combination of orthographic processing (irregular word reading) and oral comprehension provided a slightly stronger model of reading comprehension than that of phonological recoding (nonword reading) and oral comprehension in the current sample of children in the middle primary school years. The model incorporating orthographic processing, rather than phonological recoding, accounted for 6% more variance in reading comprehension. It is acknowledged however that this is not a large increase and that the predictive power of phonological recoding versus orthographic processing may vary from sample to sample.

CHAPTER 5. DISCUSSION

The findings of the current study on the relationship between reading comprehension and the selected predictor variables will be examined in three sections: 1) word reading skills, 2) language, and 3) memory. Following these sections, the focus turns to the adequacy of traditional models of reading comprehension, such as the *simple view,* for children who are no longer novice readers. In conclusion, there is a discussion on the implications of the findings for children's reading comprehension and for the development of programs designed to enhance reading comprehension skills.

5.1 Word Reading Skills

Word identification, specifically orthographic processing (irregular word reading), was the strongest predictor of reading comprehension in this study. It has been argued that the inclusion of children with poor word reading skills can confound studies researching poor reading comprehension, making it difficult to disentangle causal relationships (Nation & Snowling, 2000). Poor readers were nevertheless included in the current sample since the aim was to formulate a model of reading comprehension in a normal sample and since word reading skills are a fundamental prerequisite for reading comprehension, word reading skills could not be excluded. If large numbers of poor readers had been included in the sample, this could have potentially confounded poor reading comprehension with inadequate word reading skills. However, poor readers were not over-represented in the current sample.

The finding that word identification skills are an important predictor of reading comprehension, even after children have acquired basic decoding skills which is usually achieved by grade 2, is consistent with the findings of Carver (1998). In a sample of 135 primary school students in grades 1-6, Carver found that the level of word identification, which he referred to as “pronunciation level”, was an important determinant of reading comprehension level in all grades, including grade 6. Pronunciation level was measured using a test consisting of both regular and irregular real words.

The results of the current study provide support for the hypothesis that irregular word reading is dependent on a range of other skills. Hence, irregular word reading ability is a particularly strong predictor of reading comprehension because it captures the variance from a variety of other measures. Phonological recoding, reading speed, receptive vocabulary and verbal WM (backward digit span) were all found to be significant independent predictors of irregular word reading.

The findings are compatible with Tunmer and Chapman’s (1998) research demonstrating that irregular word reading is dependent on both the ability to convert letters to sounds (phonological recoding) and the ability to instantiate the meaning of the word from the context in which it occurs. It is therefore to be expected that phonological recoding and irregular word reading will be highly correlated in normal samples.

Chapter 5 Discussion

The results of the present study confirm that irregular word reading ability is closely associated with language ability, particularly semantic skills, since receptive vocabulary was an independent predictor of irregular word reading. This is consistent with previous research suggesting a strong relationship between irregular word reading and semantic skills. As noted above, Tunmer and Chapman (1998) showed that children use context to help identify irregular words. The ability to use context effectively, or the ability to instantiate, requires a semantic analysis, which is dependent on language skills.

Research suggests that skilled reading comprehenders are better at instantiating than poor reading comprehenders (see Oakhill,1983). Nation and Snowling (1998) argue that poor comprehenders have a less developed semantic memory system and that reduced sensitivity to contextual information impacts on their ability to read (irregular) words that are typically read with support from semantics. As a result, Nation and Snowling (1998) predict that the word knowledge of poor comprehenders will increasingly lag behind that of children with normal semantic processing skills. Cunningham and Stanovich (1991) suggest that the development of irregular word reading, or orthographic processing skills, is strongly linked to general verbal ability.

Performance on the irregular word list in the current study may therefore have been a reflection, not only of word reading skills, but also of verbal intelligence and exposure to language generally. Interestingly, the National Adult Reading Test (NART), which is a reading test of 50 irregularly spelled words, is commonly used as a test of premorbid verbal intelligence in adults (Spreen & Strauss, 1998). Performance on the test has been found to be dependent on crystallized intelligence (previous knowledge) rather than fluid intelligence which involves on-line processing and to which WM is a major contributor.

Cunningham and Stanovich (1998) contend that orthographic processing skills are strongly associated with the amount of prior exposure to print and reading experience. However, exposure to print was not found to be an independent predictor of irregular word reading in the current study. This may have been because receptive vocabulary was a stronger predictor of irregular word reading than exposure to print and receptive vocabulary may have accounted for much of the variance that exposure to print contributed to irregular reading.

A post-hoc analysis supported this position. The correlation between irregular word reading and exposure to print was $r = .36$, $p < .01$, but, after controlling for receptive vocabulary, the correlation between the two variables was substantially reduced, $r = .18$, $p < .05$. Thus, it seems that the relationship between irregular word reading and exposure to print was partly underpinned by receptive vocabulary.

Exposure to print made a small independent contribution to reading comprehension beyond age, general intellectual ability and irregular word reading. It was argued in the Introduction section that this might be the case, since exposure to print familiarizes children with typical narrative format and research by Cain (1996) shows that knowledge of narrative format is associated with better reading comprehension.

This finding also provides further support for the body of research by Cunningham and Stanovich (e.g., Stanovich et al., 1996) showing a significant association between exposure to print and reading comprehension. Cunningham and Stanovich are of the view that exposure to print improves reading comprehension by enhancing language skills. A further post-hoc analysis revealed that the partial correlation between exposure to print and receptive vocabulary, after controlling for age and general intellectual ability, was $r = .35$, $p < .01$. That is, the measures shared 12% of their variance. Although the results confirm Cunningham and Stanovich's hypothesis that exposure to print has a significant relationship with receptive vocabulary, the direction of this relationship cannot be determined since although exposure to print may help build up vocabulary, children with better vocabulary may be more avid readers.

Reading speed may add to the prediction of reading comprehension beyond the contribution of phonological recoding. Indeed, reading speed had a slightly stronger relationship with reading comprehension (r =.55, p<.01) than phonological recoding (r = .48, p<.01), after controlling for age and general intellectual ability. The measure of reading speed involved text reading, which included the reading of both regular and irregular words. The relationship between reading speed and phonological recoding (nonword reading), $r = .50$, $p < .01$, was much weaker than that between reading speed and irregular word reading $r = .72$, $p < .01$, after controlling for age and general intellectual ability. In the current study, reading speed was not found to be an independent predictor of reading comprehension after irregular word reading had been included in the prediction and it was a significant independent predictor of irregular word reading.

This clearly has implications for models of reading comprehension such as the *simple view* in which the variable selected to represent word reading skills is phonological recoding. That is, while irregular word reading incorporates all of the variance attributable to reading speed, phonological recoding does not. The case for the inclusion of irregular word reading in a model of reading comprehension will be argued in Section 5.4.2 on the development of a new model.

5.2 Language Skills

Oral comprehension, receptive vocabulary and receptive grammatical skills were strongly correlated with reading comprehension, even after controlling for age and general intellectual ability. The relationship between reading comprehension and both oral comprehension and receptive vocabulary was of a similar magnitude, whilst the relationship between reading comprehension and receptive grammatical skills was slightly weaker. The language variables were much more strongly correlated with reading comprehension than the memory variables.

It has already been established that language skills are a strong predictor of reading comprehension in previous studies, (Baddeley et al., 1985; Gottardo et al., 1996;

McKeown et al., 1983; Roth & Perfetti, 1980; Stanovich et al., 1996). Storch and Whitehurst (2002) found that reading comprehension was determined by multiple factors including prior word reading skills, current word reading skills and current language ability. In pre-school and early primary school language skills were closely associated with word reading skills. The pattern of relationship changed when children reached the 3rd grade and verbal ability and oral language skills became independent predictors of reading comprehension. Language skills were assessed using a number of measures, including the PPVT, the test of receptive vocabulary that was also used in the current study.

Storch and Whitehurst (2002) argue that early oral language skills provide the basis for the development of the advanced oral language skills needed for comprehension in the mid- primary school years. They suggest that the remediation of reading comprehension deficits in grades 3 and 5 is best accomplished by focusing on improving oral language skills, such as vocabulary or syntax, whereas remediation in the early primary school years may be better concentrating on enhancing word recognition abilities through phonological training.

In the current study with children in grades 3, 4 and 5, both phonological recoding skills and receptive vocabulary were found to be independent predictors of reading comprehension, but receptive vocabulary was the stronger predictor of the two. While receptive vocabulary accounted for 45% of the variance in reading comprehension, without controlling for age and general intellectual ability, phonological recoding skills only accounted for 27%.

The independent contribution of receptive vocabulary to reading comprehension was comparatively low. In the final analysis, when entered with irregular word reading, exposure to print, oral comprehension, grammatical skills and verbal learning and retrieval, receptive vocabulary accounted for less than 1% of the variance in reading comprehension. Of the three language variables, oral comprehension made the largest independent contribution to reading comprehension in this analysis (6% of the variance), followed by receptive grammatical skills (1% of the variance). It can be concluded that there is much overlapping variance between receptive vocabulary and the other variables (e.g., irregular word reading and the other language measures), making the unique contribution of receptive vocabulary to reading comprehension much lower than the initial correlational analyses suggested.

As discussed in the previous section, the strong relationship between receptive vocabulary and irregular word reading was consistent with the findings of Tunmer and Chapman (1998) with a normal sample and also with that of Nation and Snowling (1998) with groups of poor and adequate comprehenders. In the current study receptive vocabulary was the strongest predictor of irregular word reading after phonological recoding and reading speed.

Unlike receptive vocabulary, the contribution of oral comprehension and receptive grammatical skills to reading comprehension were not as affected by the entry of irregular word reading. Oral comprehension still made a considerable unique contribution to reading comprehension even after the entry of irregular word reading. The contribution of receptive grammatical skills to reading comprehension was also not greatly attenuated by the entry of irregular word reading and receptive grammatical skills were found not to make a significant contribution to irregular word reading in a regression analysis.

Grammatical skills on the TROG did however, make a small independent contribution to reading comprehension. Nevertheless, as noted in Section 4.1.3, the strength of the relationship with reading comprehension may have been attenuated by a ceiling effect.

Stothard and Hulme (1996) investigated the relationship between reading comprehension and performance on the TROG in three groups of 7- to 8- year-old children: a group of poor comprehenders with normal word reading skills, a group of adequate comprehenders matched with the poor comprehenders on word reading skills and a younger group of adequate comprehenders matched for comprehension age to the poor comprehenders. The results showed that poor comprehenders performed significantly worse on the TROG than the adequate comprehenders. However their performance was similar to that of the younger children matched for reading comprehension level. The poor comprehender group exhibited a marked discrepancy between their verbal and performance IQ scores on the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) which was not apparent in the chronological age controls or the comprehension-age matched controls. The poor comprehenders were particularly impaired on the Vocabulary and Similarities subtests. Their raw scores on these subtests were not however significantly different from the younger comprehension-aged matched controls. Their lower level of comprehension skills was therefore compatible with their level of verbal skills.

Stothard and Hulme (1996) argue that the weaker performance on the TROG was not causally related to reading comprehension deficits and that the inferior performance on the TROG was related to weak verbal-semantic skills. This was concluded because of the discrepancy between verbal and performance IQ scores of the poor comprehenders on the WISC-R. However, this may not have been entirely warranted since the WISC-R does not include tests of receptive grammar and, as with the TROG, the raw vocabulary scores of the poor comprehenders were comparable to those of the comprehension-aged matched group. The possibility of a direct relationship between poor comprehension and inferior performance on tests of receptive grammar cannot therefore be ruled out.

The strongest independent predictor of reading comprehension amongst the language variables was oral comprehension, which provides support for its inclusion in models such as the *simple view*. Although the correlation between reading comprehension and oral comprehension was similar to that between reading comprehension and receptive vocabulary, the independent contribution of oral comprehension to reading comprehension was more than five times that of receptive vocabulary.

It is acknowledged that the strong relationship between reading and oral comprehension in the current study may be a reflection of methodological issues relating to the measurement of oral comprehension. That is, there was a word reading component to the task since the multiple-choice questions were presented in a written format.

However, efforts were made to minimize the impact of word reading skills. Questions for each story passage were printed on separate pages in the booklet and children turned to the relevant questions just prior to the passage being played on the tape recorder. The questions and the four answer alternatives were read aloud to the children after the passage had been presented and children were instructed not to mark their answers on the sheet prior to this. Information was repeated as necessary. Children were therefore able to complete the task with minimal word reading skills. It is therefore argued that, although this aspect of the oral comprehension measure may have lead to a slightly higher correlation between the reading and oral comprehension measures, since more competent readers may have had a slight advantage, it did not greatly influence the findings.

5.3 Memory

The following section on the implications of the findings for the relationship between reading comprehension and memory focuses on four main areas: 1) comparison of the relationship between reading comprehension and the visuospatial, as opposed to the verbal memory tasks; 2) the importance of adequately controlling for word reading skills, 3) the lack of relationship between reading comprehension and the measure of WM inhibition; and 4) the influence of verbal LTM on reading comprehension. It is concluded that reading comprehension involves an interaction between short-term and long-term memory processes and that the tasks used in the current study do not measure this ability.

Contrary to the findings of much previous research, all of the memory measures (except the measure of WM inhibition on the RAVLT), including the visuospatial measures, were significantly correlated with reading comprehension. However, the strength of association was not as strong as that between reading comprehension and either the word reading or the language variables.

The correlations between reading comprehension and both the verbal and visuospatial tasks were relatively weak and of a similar magnitude. The finding that performance on the visuospatial STM measure, the Corsi block task, was significantly correlated with reading comprehension is consistent with the findings of Bayliss and her colleagues (Bayliss et al., 2003; Bayliss et al., in press). These researchers found that there was a strong significant relationship between performance on the Corsi block task presented on a touch screen computer (as in the current study) and performance on the Sentence Completion Forms of the NFER-Nelson Group Reading Test. As reported in the Method section, performance on the PAT, the measure of reading comprehension in the current study, is strongly correlated with performance on the NFER-Nelson Group Reading Test.

The relationship between the reading comprehension and the Corsi block task was much weaker in the current study (*r* =.36, without controlling for age or general intellectual ability) than that reported in Bayliss et al., (in press), *r* =.68, and performance on the Corsi was not found to be an independent predictor of reading comprehension after controlling for language skills. Bayliss and her colleagues (Bayliss et al., 2003; Bayliss et al., in press) did not control for other variables, and it is therefore possible that the relationship between the Corsi and reading comprehension would no longer have been significant had these other variables been taken into account.

The Corsi task can be viewed as a simple span task, involving only visuospatial storage, since the sequence of blocks is recalled in the order in which they are presented. In the Bayliss et al., (in press) study with 56 children, it was found that complex span tasks did not correlate with reading comprehension any more strongly than did the simple span tasks. This was the case in the current study. In the verbal tasks, backward digit span and triplet number span did not correlate with reading comprehension any more strongly than forward digit span, and amongst the visuospatial tasks, the triplet block span task did not correlate any more strongly with reading comprehension than the Corsi task.

Although the Corsi task is frequently used in the research literature, Berch et al., (1998) point out that surprisingly few studies have been undertaken to address the underlying cognitive processing demands of the task. Bayliss et al., (in press) conjecture that the Corsi task may be more than a measure of visuospatial storage, since constructing a path between blocks in the Corsi display may recruit executive ability. Hence, the Corsi task may be better classified as a complex span task. Research by Vandierendonck et al., (2004) also supports the idea that performance on the Corsi task involves both short-term visuospatial storage and executive control (at least at longer block sequences)

However, presumably, the triplet block task, which is a complex span task, also has both a visuospatial storage component and an executive control component. In the current study, the Corsi task made a non-redundant contribution to reading comprehension, whereas the triplet block task did not. The triplet block span task entailed remembering the position of the third block from each triplet sequence in order of presentation. The Corsi block task may be a purer measure of visuospatial sequencing than the triplet block task. It is believed that the block sequences in the Corsi are remembered as an overall path forming a gestalt, rather than by remembering the position of each block separately and then subsequently combining them together (Berch et al., 1998). In contrast, in the triplet block task, the block sequences have to be mentally combined and there is no initial impression of a pattern of block locations. The Corsi task may therefore provide a purer measure of the speed with which visuospatial information is integrated than complex visuospatial span tasks, such as the triplet block task.

Visuospatial processing is believed by many researchers to be an important component of word identification and text reading since a word is recognized as a pattern of letters and text reading involves keeping track of the position of words on a page (Harris, 2002; Williams, 2001). It is therefore unclear why the Corsi remained a significant predictor of reading comprehension after controlling for irregular word reading but not after controlling for the language variables. Although some of the variance in performance on the Corsi was accounted for by the language tasks it is unlikely that this is reflective of children using verbal strategies to perform the task. That is, verbal strategies (e.g., top left, bottom right, middle left) are not likely to be an effective method of recalling longer block sequences in the Corsi.

In the current study none of the verbal STM variables made an independent contribution to reading comprehension after controlling for word identification skills. Poor word reading skills are known to be associated with verbal STM deficits (Hulme & Snowling, 1992). Verbal STM is believed to involve the storage of items in a phonological (sound-based) format (Gathercole & Baddeley, 1993). It therefore follows that weak phonological skills will affect performance on verbal STM tasks (Baddeley, Gathercole, & Papagno, 1998; Gathercole, 1998). Weak phonological skills have also been found to be causally related to problems with phonological recoding as measured by nonword reading (Baddeley & Gathercole, 1992; Stothard & Hulme, 1995).

As previously discussed, irregular word reading skills are built up through a combination of phonological recoding skills and the ability to use contextual cues, which is underpinned by language skills. If weak phonological skills impact on phonological recoding, they will also affect the ability to read irregular words and weak phonological skills will result in generally poorer word reading. Poor word reading and verbal WM deficits are therefore likely to occur concurrently.

There is little tangible evidence that verbal WM is an independent predictor of reading comprehension. Many researchers fail to control for word reading adequately, as well as language skills. Failure to do so may equivocate the findings.

For example, Leather and Henry (1994) compared the power of phonological awareness, word span, two WM tasks and vocabulary to predict reading comprehension on the Neale Analysis of Reading Ability, in which the text is taken away prior to answering the comprehension questions. The WM tasks were listening span, which was adapted from the Daneman and Carpenter (1980) sentence span task, and counting span, which involved counting the dots on a series of cards and recalling the number of coloured dots on each card in order. The listening span task was found to be the best predictor of reading comprehension, while counting span best predicted arithmetic ability. In their study the correlation between listening span and reading accuracy measured on the Neale was r =.60, while the correlation between reading comprehension and listening span was r =.61.

It is likely that if, in the Leather and Henry (1994) study, reading accuracy had been entered in the regression analysis prior to the listening span task, the listening span task would no longer have been a significant predictor of reading comprehension. The researchers also note in their discussion that partialling out vocabulary scores had a considerable effect on listening span scores.

The findings of Seigneuric et al., (2000) are also difficult to interpret. Like Leather and Henry (1994), Seigneuric and his colleagues reported differing strengths of correlation between reading comprehension and different types of WM task. Reading comprehension was measured on a cloze task with the text available. The WM-words task, which involved spotting the odd-one-out from groups of four words and recalling them in the correct order, had the highest correlation with reading comprehension. This is not surprising since performance was dependent on the processing component of the task which was judging the semantic relationships between the words and, in the same study, a strong relationship was reported between reading comprehension and vocabulary, r =.58.

In the regression analyses, only WM-words and WM-sentences made a significant independent contribution to reading comprehension, after controlling for vocabulary and decoding, while the WM task containing digits did not. The result of this analysis may have been very different, however, if decoding errors had been selected as the variable to represent word identification skills rather than decoding time. Decoding errors had a slightly higher correlation with reading comprehension than decoding time and was correlated with the verbal and numerical WM tasks, in contrast to decoding time, which was not. The WM tasks may therefore have failed to make a significant independent contribution to reading comprehension after controlling for decoding errors and vocabulary.

In the present study, the WM tasks containing digits were much less strongly correlated with reading comprehension than either the word identification or the language variables and failed to make an independent contribution to reading comprehension. It can be concluded that the current findings are not incompatible with those of Leather and Henry (1994) and Seigneuric et al., (2000).

The relationship between reading comprehension and verbal WM was underpinned by word identification skills in the present study, rather than by language skills. The correlation between reading comprehension and the RAVLT, which is a language based task involving the recall of a list of 15 words, and which has both a short-term and a longer-term learning and retrieval component, was slightly weaker than that between reading comprehension and the tasks containing digits. The measure of long-term learning from the RAVLT was however the only memory measure to make an independent contribution to reading comprehension, albeit small.

Performance on the RAVLT was expected to be more influenced by language skills since strategies such as grouping words semantically (e.g., drum and bell can be classified as musical) or alternatively, combining the words into a narrative (e.g., the turkey of the farmer with the hat on was in the garden of the house by the river) could be used to facilitate recall. This was not found to be the case however and a post-hoc correlational analysis revealed that receptive vocabulary (PPVT-III) and receptive grammatical skills (TROG) were no more strongly correlated with performance on the RAVLT than with the STM tasks containing digits, such as forward and backward digit span. It can be concluded that most children in the age group tested do not routinely make use of semantic mnemonic strategies to facilitate performance in this type of test.

The reason that the STM tasks containing digits have slightly higher correlations with reading comprehension than with measures from the RAVLT may be related to the fact that the RAVLT does not have a sequencing component like the other STM tasks. Both phonological recoding and the learning of new vocabulary have a sequencing component and both are strong predictors of reading comprehension. Both require the storage of unfamiliar phonological sequences and the phonological loop is believed to have evolved specifically for this purpose (Baddeley et al., 1998a). Short term memory tasks would therefore be expected to be stronger predictors of reading comprehension if they have a phonological sequencing component in which words or digits must be placed in temporal order.

A recent study by Gelfand and Bookheimer (2003) using fMRI showed that the phonological loop may involve several brain areas. Different components of the phonological loop may be recruited depending on the demands of the task. For example, Gelfand and her colleagues found that the left supramarginal gyrus of the frontal lobe may be specific to the sequencing of phoneme segments. It may be that tasks such as the RAVLT do not draw on this ability to the same degree as STM tasks which involve temporal sequencing. This would also explain why the correlations between the RAVLT and the verbal span tasks (forward and backward digit span and triplet number span) were very weak.

The measure of WM inhibition on the RAVLT was the only memory task that showed no relationship with reading comprehension either before or after controlling for other variables. The evidence for the theory that reading comprehension deficits are associated with problems in inhibiting irrelevant information from WM is, in fact, not very conclusive. It is based on the findings of studies with small groups of poor comprehenders in which poor comprehenders remember fewer words which are in the final position in sentence span tasks and also remember more irrelevant words which are not in the final position. It is not clear whether this phenomenon may be due to the inferior language skills of poor comprehenders, making them less able to use semantic cues to facilitate recall.

The lack of a relationship between reading comprehension and WM inhibition in the current study may indicate that there was a problem with the validity of the measure of WM inhibition. The measure used was the number of intrusion errors on the RAVLT, an episodic word list learning task with five initial trials and a delay trial administered 30 minutes later. There was no sequencing component to the task, as the words did not have to be recalled in the order of presentation. The RAVLT was the first test administered in the one hour individual test session. Hence, although interference may have been generated from the intervening verbal tasks on the delay trial, there was little to interfere with the recall of the words in the first five trials. Contrary to the tasks in studies which have shown a relationship between reading comprehension and WM inhibition, the task used in the current study did not have a sequencing component and performance on the task may not have been as susceptible to interference. It is possible that the task may not have been adequately challenging to provide a valid measure of WM inhibition.

The issue of whether there is a relationship between reading comprehension and WM inhibition requires further research using more face valid measures of WM inhibition which do not have a language component. Steps must also be taken to control for word reading skills (either by statistically controlling for word reading skills or by the exclusion of children with poor reading skills). Dempster and Corkhill (1999) note that children with word identification problems (reading disabled children) perform poorly on tasks which are used to ascertain an individual's susceptibility to interference such as the Stroop, the Wisconsin card sorting task (WCST) and the Brown-Peterson task.

After the inclusion of both the word reading and the language variables, only verbal learning and retrieval, the measure of longer term verbal learning and retrieval, made a small independent contribution to reading comprehension. This is of interest in view of the fact that the focus of attention in reading comprehension research has been on short-term rather than LTM processes and that none of the STM variables (including the WM measures) made an independent contribution to reading comprehension.

As discussed, the relationship between reading comprehension and the RAVLT was not due solely to the fact that the RAVLT contains word stimuli rather than digits since the STM measure from the RAVLT made no independent contribution and demonstrated the weakest relationship with reading comprehension of all the memory measures after controlling for age and general intellectual ability. This suggests that the measure of verbal learning and retrieval makes a contribution to reading comprehension because it is a measure of the ability to retain and retrieve information after a delay, rather than a measure of immediate memory (i.e., STM).

There is some support from research on reading comprehension in adults that LTM may play an important role in reading comprehension. Butcher and Kintsch (2003) contend that LTM provides the schema or knowledge which is the basis for constructing a model of the situation in the text. According to Kintsch's (1988) Construction-Integration model of reading comprehension, problems with the recall of details from the text can be circumvented by using information from LTM to compensate for gaps in comprehension. Ericsson and Kintsch (1995) proposed that the STM concept accounts for the use of WM in unfamiliar activities but does not provide sufficient storage capacity for WM in skilled complex activities, such as reading comprehension.

Ericsson and Kintsch (1995) extended the concept of WM and subdivided it into long-term working memory (LT-WM) and short-term working memory (ST-WM). While information in LT-WM is stored in a durable form, ST-WM is used for the temporary storage of information. Ericsson and Kinsch argue that in skilled well-practiced tasks, such as reading comprehension, a model of the situation in the text is stored in LT-WM and kept directly accessible by means of retrieval cues in ST-WM. According to Ericsson and Kintsch, during the reading of a text, when a clause or sentence is completed, the new information is integrated into the model of the situation in LTM. When the next sentence is processed, some elements of the model are kept in STM, both to provide context and also to serve as retrieval cues to access the model in LTM. They contend that the use of a combination of LT-WM and ST-WM to allow the storage of large amounts of information is an acquired skill.

In line with this shift in focus in research on adult reading comprehension, Hannon and Daneman (2001) have developed a new tool, the component processes task, to measure a reader's ability to access and integrate knowledge in LTM with information in the text and to make inferences from, and to recall details from, the text. In their study, participants read three sentence paragraphs that described the relations between a set of real and imaginary terms, for example, "a nort resembles a jet but is faster and weighs more. A burl resembles a car but is slower and weighs more. A samp resembles a burl but is slower and weighs more." Participants then responded to true-false statements measuring their ability to access and integrate LTM knowledge with information presented in the paragraph, to make inferences from information in the paragraph and to recall explicit information from the paragraph.

Hannon and Daneman (2001) found that the component processes task better predicted reading comprehension than a typical WM span task. Of all the components, high-knowledge integration was the most strongly correlated with reading comprehension, $r = .58$, $p<.01$. This supports the contention that LTM plays an important role in reading comprehension and that reading comprehension is dependent on the development of a skilled interaction between short-term and LTM processes.

According to Ericsson and Kintsch (1995) the development of the ability to syncronise short-term and LTM processes to facilitate more skilled reading comprehension is achieved through practice and the ability becomes well honed by adulthood. What then are the implications for children's reading comprehension? There is some indication that LTM may play a role in children's reading comprehension. Cain et al., (2001) found that poor comprehenders had more difficulty retaining new verbal knowledge following a delay than adequate comprehenders, even when their short-term retention did not differ markedly. Cain et al., (2001) acknowledge however that there were ceiling effects in both the immediate and delayed recall measure in this study and the sample size was small (13 in each group).

It is concluded that memory tasks designed to reflect the interaction of short and LTM processes may be stronger predictors of children's reading comprehension than either the complex span tasks designed to assess the contribution of STM or simple list learning tasks aimed at measuring longer-term retention and retrieval.

The test of longer-term retention and retrieval used in this study was an episodic memory task rather than a test of semantic memory. Episodic memory involves memory for personally experienced events whilst semantic memory involves the storage of world knowledge, including vocabulary (Banich, 1997). Although measures of semantic memory would be expected to have a stronger relationship with reading comprehension than tests of episodic memory, the measure of retrieval from episodic memory made a stronger unique contribution to reading comprehension than any of the verbal STM measures. It is clearly evident that STM processes alone cannot account for children's reading comprehension since the amount of information to be remembered in the average story far exceeds the storage capacity of STM and children must form some long-term representation of the text.

In the current study in which children had ready access to the text, problems with encoding information in the text could be circumvented by re-reading the text to facilitate the build up of a coherent situational model. In this context, the comprehension questions provide retrieval cues, which may trigger a search for the relevant information. That is, the questions make a reader aware that there is a gap in their comprehension of the text. Comprehension questions can therefore be answered by comprehending the text at the time of reading or by going back over the text to clarify the gap in comprehension. Children's ability to monitor their comprehension of the text (which may be achieved by the adept use of retrieval cues in STM) is not being measured in this instance.

It is likely therefore that the dynamics of the relationship between STM and LTM processes will vary depending on the demands of the comprehension task. When children have access to the text while answering the comprehension questions and have ample time to re-read sections to clarify ambiguities, STM did not play a crucial role in determining reading comprehension. More research is required on children's reading comprehension using WM tasks that have been developed to look at the interplay between short and LTM processes. It would be of great interest to investigate the impact of the mode of presentation of the reading comprehension tasks on the findings. No past research has addressed this issue, even though the power of different measures to predict reading comprehension may vary dramatically according to how reading comprehension is assessed.

5.4 Models of Reading Comprehension

5.4.1 Implications For The Simple View

The additive variant of the *simple view* proved to be reasonably effective in accounting for the variance (43%) in reading comprehension in the current sample of 180 children in the 8- to 12-year-old age group. However, in this normal sample, a multiplicative combination of phonological recoding and oral comprehension did not significantly contribute to the prediction of reading comprehension over and above an additive combination of these variables.

This finding is consistent with those of both Dreyer and Katz (1992) and Joshi and Aaron (2000). However, the analysis that Joshi and Aaron used as a basis for their conclusions is statistically incorrect (see Section 2.1.1.1). In Dreyer and Katz (1992), the amount of variance accounted for in reading comprehension was 44% in grade 3 children and 47% in grade 5 children. They observe that “the sum of decoding (phonological recoding skills) and listening (oral) comprehension accounts for so much variance in reading comprehension that there may be little room left for improvement by the product” (p.174). Joshi and Aaron (2000) argue, however, that the product index is a better formula because it makes allowances for nonreaders. This is not a factor with the current sample in which children were in the mid-primary school years and had all developed some level of word reading skills.

In Hoover and Gough’s (1990) original study in which they tested the predictive validity of their multiplicative formula by administering decoding and comprehension tests to English-Spanish bilingual children in grades 1-4, the additive model accounted for between 72% to 85% of the variance in reading comprehension, depending on grade level. In grade 3 children, the multiplicative model made a significant contribution to reading comprehension and contributed 7% of the variance beyond the contribution of the additive model.

It is of note that in Hoover and Gough's (1990) study the tests were conducted in English and the sample contained children with low oral English skills. The oral comprehension skills of these children would be very poor, although they may have been competent readers of English nonwords since Spanish, like English, is a phonetic language. Although English has a deeper orthography than Spanish, the nonwords were all regular and therefore like Spanish, the spelling was completely phonetically based. The multiplicative formula, in which if oral comprehension is nil, reading comprehension is also nil, would therefore better predict their comprehension of written text than the additive formula. In contrast, the additive formula may have better accounted for the performance of children who were not grossly impaired in either English comprehension or the reading of English nonwords.

Hoover and Gough (1990) employed parallel tests of oral and reading comprehension from the Interactive Reading Assessment System (IRAS) (Calfee & Calfee, 1981). In the reading comprehension test children read a narrative passage aloud for the first four levels and silently in the last five levels. Children were then required to recount as much of the story as they could remember. After completing the free recall task, any story elements that are not adequately recalled were probed with the corresponding question. Scores were allocated according to whether the story elements were remembered in the free recall or the cued recall condition with more points being allocated for remembering in the free recall condition. Oral comprehension was assessed using the same procedures except that the narrative passage was read out loud by the examiner.

Both the oral and reading comprehension tests therefore had very similar demands and performance in both was very dependent on memory since children did not have access to the text and more points were allocated for recall in the non-cued condition. For adequate readers, children's performance on the oral and reading comprehension test would therefore be expected to be very comparable in this study and it is not surprising that a combination of phonological recoding and oral comprehension predicted such a substantial proportion of the variance in reading comprehension.

It can be concluded that the amount of variance accounted for by phonological recoding skills and oral comprehension will vary greatly depending on how similar are the measures of reading and oral comprehension. Hoover and Gough (1990) argue that if the *simple view* is to be adequately tested, parallel materials must be employed so that if narrative material is used for example in the oral test, then narrative material rather than expository material, should be used in the reading test. This does not however imply that comprehension should necessarily be assessed in the absence of the text in the reading test. Indeed, in order to make the measures less of a memory test and more of an assessment of comprehension, the demands of the oral comprehension test could be better equated to the demands of the reading comprehension test in which the text is available or by allowing participants to re-listen to sections of the narrative.

The additive combination of phonological recoding skills and oral comprehension better fit the data in the current normal sample. From the discussion above, the degree to which the additive or the multiplicative model fit the data seems to depend on the sample characteristics. While a multiplicative model may be a better model in non-normal populations (e.g., in children with dyslexia or language disorders) there is no evidence that this is the case in normal populations.

5.4.2 Alternative models

According to the *simple view* reading comprehension consists of only two parts, decoding (word reading) and linguistic (oral) comprehension. Both of these components are necessary and neither is sufficient by itself (Hoover & Gough, 1990). In their description of the constituents of the *simple view,* Gough and Tunmer (1986) argue that word reading ability is fundamentally dependent on knowledge of letter-sound correspondence rules and that the purest measure of this ability is nonword reading. However this position alters slightly in Hoover and Gough (1990), since although the pronunciation of isolated nonwords is recommended as the best measure of word reading for beginning readers, the pronunciation of isolated real words is recommended as the measure for skilled readers.

In the current study, irregular word reading was a stronger predictor of reading comprehension than nonword reading. Apparently, irregular word reading captured all of the variance in reading comprehension associated, not only with nonword reading, but also with reading speed and verbal WM (backward digit span). Irregular word reading also accounted for much (although not all) of the variance in reading comprehension contributed by receptive vocabulary. Not surprisingly, the predictive power of the *simple view* was found to be improved by substituting irregular word reading for phonological recoding skills. Whilst a linear combination of nonword reading and oral comprehension accounted for 43% of the variance in reading comprehension, a linear combination of irregular word reading and oral comprehension accounted for a further 6% of the variance, accounting for 49% of the variance in reading comprehension in total. This finding is hard to reconcile with Hoover and Gough's (1990) contention that reading comprehension consists of only two parts: phonological recoding skills and oral comprehension.

Text reading speed was not found to be an independent predictor of reading comprehension in the current study. In fact the issue of whether speed is an independent component of word reading skills is a contentious one (Carver, 1998). Joshi and Aaron (2000) did find that the addition of a speed factor to the *simple view* increased the prediction of reading comprehension from 69% to 76%. The speed index, which was calculated for each of the 40 primary school grade 3 children, was based on the speed of identifying letters of the alphabet rather than whole words. The letters were presented on a piece of paper one below the other. The speed index calculated may therefore not have been specific to reading and may be indicative of the speed of visual scanning or processing generally.

It can be concluded that irregular word reading is the most parsimonious measure of word reading skills to incorporate in a model since it accounted for not only the variance in phonological recoding skills (nonword reading), but also in reading speed. Arguably, it is therefore the most inclusive measure of word reading skills, covering all aspects of this ability.

The results of the current study are most supportive of Perfetti's model of comprehension in which *Reading Comprehension = Language Comprehension + Decoding + X*, where *X* is small relative to the other two variables. In Perfetti's model "decoding" or word reading, encompasses the reading of both regular and irregular words and the model allows for the effects of other factors besides general language comprehension and word reading.

Perfetti (1977) maintains that the effects of other factors are small relative to oral comprehension and word reading and this certainly proved to be the case in the current study. Four variables: receptive vocabulary, receptive grammar, exposure to print and verbal learning and retrieval, each made small independent contributions to reading comprehension but together only accounted for a further 5% of the variance after the addition of oral comprehension and word reading. It can be concluded that the model is not much improved by the addition of these variables and the two component additive model, *reading comprehension = orthographic processing + oral comprehension,* which accounts for 49% of the variance in reading comprehension skills after controlling for age and general intellectual ability, provides a sufficiently parsimonious model of reading comprehension skills in normal populations.

5.5 Development and Remediation of Reading Comprehension

The formulation of a model of reading comprehension in terms of a linear combination of oral comprehension and orthographic processing may not appear to have any practical application. However, the model does have some implications for remediation programs or programs designed to improve reading comprehension in normal populations. Word reading and language skills were identified as the most powerful predictors of reading comprehension, suggesting that remediation programs should target these skills.

Irregular word reading is dependent on the ability to use context to derive meaning. Comprehension has been defined as the extraction of meaning. The reading of irregular words is therefore dependent on comprehension and vice versa; that is, there is some degree of co-dependency between the two skills. This implies that reading comprehension skills can be improved by focusing on improving the skills which contribute to irregular word reading.

Irregular word reading was strongly associated with a measure of receptive vocabulary. There is some evidence that improving vocabulary can enhance reading comprehension. For example, in McKeown et al., (1983) a sample of 41 children in grade 4 were taught 104 difficult words over a 5-month period. These children and 41 uninstructed controls, who were matched on pre-instruction vocabulary and comprehension ability, performed tasks to measure accuracy of word knowledge, speed of lexical access, and comprehension of stories containing the taught words. The results supported the hypothesis that intensive vocabulary instruction designed to promote vocabulary knowledge enhances text comprehension.

Although vocabulary enhancement may improve comprehension, a more effective method of improving reading comprehension may lie in circumventing the processes involved in the reading of irregular words. Children are often asked to read silently material that is far above their ability level and are encouraged to guess words that they are unable to identify. Tunmer and Chapman (1998) showed that children use a combination of phonological recoding skills and context to guess the pronunciation of irregular words. However, they are frequently unsuccessful and Gough (1983) found that these guesses are often wrong.

The results of Carver’s (1998) study demonstrating a strong relationship between reading comprehension and word reading, even in the latter years of primary school, lead him to conclude that reading comprehension can be improved by emphasizing instruction that will improve word pronunciation level. How then can this be achieved? Lundberg and Olofsson (1993) propose that reading comprehension can be improved by providing fast feedback for difficult words. The researchers used a computerized text to speech program in which the reader of a text presented on a computer screen can request the immediate pronunciation of a problem word encountered.

Lundberg and Olofsson (1993) compared the effectiveness of this type of remediation program with that of a traditional remediation program which focused on the teaching of lists of unrelated words or nonwords to strengthen word reading ability. Although the researchers do not describe the traditional remediation program in detail, presumably, the teaching of words in a list would entail both word identification and the provision of the meaning of unfamiliar words. In contrast, the computer based remediation program provides the reader with meaningful texts in which children have to monitor their own reading performance and have to decide when help is necessary (that is, to request help in identifying a particular word). Interestingly, although both types of remediation program had similar positive effects on word identification ability, this was not the case for reading comprehension.

The results showed that when compared to the traditional program, the computer-aided reading program had a positive effect on the reading comprehension of older children in grades 4,6 and 7 but not on their word identification skills. The computer-aided program was no more effective that the traditional program in increasing the reading comprehension or the word identification skills of beginner readers.

The teachers who administered the remediation programs thought that the main reason that the improvement in reading comprehension was only apparent in the older children was that these children read more difficult text passages containing a larger number of complex words and may have benefited more from the computer feedback. The younger children may also not have had the cognitive resources to cope with the metacognitive demands of the task since it requires children to monitor their own comprehension and there is good evidence that younger children are not nearly as skilled at doing this as older children. For example, younger primary school children have been found to be much poorer at detecting errors in text during reading than older primary school children (Garner, 1987; Jarvella, Lundberg, & Kalliokoski, 1992). In the older children the program appears to enhance their ability to monitor their comprehension of the text.

Their findings support Stanovich et al.’s (1996) contention that reading comprehension deficits can be due to lack of practice and exposure to print. Lundberg and Olofsson (1993) note that the group of children in the experimental group reported that they read more after training than before and were less afraid of advanced or long texts. The children’s library loan records confirmed this. It should be noted however that the sample of children in the experimental group had word reading deficits and the number of children in the experimental and control groups was small (e.g., only 8 children in the experimental older reader group and 7 children in the control group).

The findings must therefore be treated with caution and it cannot be assumed that such a program would be effective in improving the comprehension of normal readers. However, the results of the current study and that of Carver (1998) show that word reading is the strongest predictor of reading comprehension in normal samples. Computerised text-to-speech programs are a very effective method of teaching the skills involved in reading words in a text and it would be of great interest to conduct further research on the effectiveness of these programs in both normal samples and groups of poor comprehenders.

5.6 Final Conclusions

The study had two main aims. The first aim was to identify the strongest predictors of reading comprehension in a normal sample of primary school children and to investigate whether the *simple view,* in which reading comprehension is defined as the combination of phonological recoding and oral comprehension, is a satisfactory model of reading comprehension in the middle and latter years of primary school, or whether a better model could be formulated. Reading comprehension was measured with a multiple choice test in which the text is available when answering the questions.

The second aim was to investigate the relationship between reading comprehension and different types of memory. The study is unique in that it incorporated a broad range of different memory measures including measures of STM, WM and a measure of longer-term verbal learning and retrieval. Short term memory and WM tasks were presented in both the verbal and the visuospatial modalities. The verbal tasks were of two types, some containing words and others, numeric stimuli.

In the current sample of 180 primary school children in grades 3-5, word reading skills (particularly orthographic processing) and language skills were much more strongly correlated with reading comprehension than measures of either STM, WM or longer term learning and retrieval. Of the word reading, language and memory variables, only the measure of WM inhibition was not significantly correlated with reading comprehension. However, neither phonological recoding, reading speed, nor the STM and WM measures made a unique contribution to reading comprehension after controlling for orthographic processing skills.

Orthographic processing, measured by irregular word reading, was the most powerful predictor of reading comprehension and it accounted for all of the variance in reading comprehension contributed by phonological recoding skills, reading speed and verbal STM and verbal WM. There was also a strong relationship between orthographic processing and receptive vocabulary. These findings provide support for the theory that the reading of irregular words is dependent on both phonological recoding and semantic skills. Since both phonological recoding and semantic skills are strong predictors of reading comprehension in their own right, it is not surprising that irregular word reading was a particularly good predictor of reading comprehension.

An additive version of the *simple view* was found to provide a more parsimonious model of reading comprehension than a multiplicative version; that is, the multiplicative model failed to add to the prediction of reading comprehension beyond the additive model. The additive model is more appropriate for the prediction of reading comprehension in normal samples in which there are no, or very few children, with extremely poor reading or language skills. However, an additive combination of oral comprehension and irregular word reading provided a better model than the additive version of the *simple view*. Orthographic processing skills, measured by irregular word reading, provided a stronger measure of word reading skills than phonological recoding skills in the current sample of children in the mid to late primary school years. Orthographic processing skills are closely aligned to semantic skills and Nation and Snowling (1999) believe that impaired semantic skills can be causally related to poor reading comprehension.

The results support Perfetti's (1977) contention that *Reading Comprehension = Language Comprehension + Word Identification + X* with *"X"* being small relative to the other two factors. Besides orthographic processing and oral comprehension, none of the other variables made a large independent contribution to reading comprehension. Exposure to print, receptive vocabulary, receptive grammatical skills and longer term verbal learning and retrieval all made small independent contributions. Together, the addition of these four variables contributed a further 5% of the variance in reading comprehension.

The findings in relation to the memory measures were of particular interest. The relationships between the reading comprehension and the memory tasks were not as strong as the relationships between reading comprehension and the word reading and the language tasks. The visuospatial tasks were just as strongly correlated with reading comprehension as the verbal tasks. However, neither the verbal nor the visuospatial STM or WM tasks made an independent contribution to reading comprehension after controlling for word reading and language skills. The verbal memory tasks failed to make a significant independent contribution to reading comprehension after controlling for word reading skills. On the other hand, the visuospatial STM task, the Corsi block task, did make a significant additional contribution to reading comprehension after controlling for word reading skills. The measure of longer term retention and retrieval was, however, the only task to make a significant independent contribution to reading comprehension after controlling for the language variables, although this contribution was very small. It seems that in the context of the current study, in which reading comprehension was measured with the text available, memory was not an important predictor of reading comprehension.

The findings have implications for the types of memory measures used in reading comprehension research. Clearly, STM does not provide enough storage capacity for complex cognitive tasks such as reading comprehension. The type of memory required in reading comprehension requires an interaction between STM and LTM, in which new information is combined with information already stored in LTM. WM tasks designed to tap this ability are likely to be stronger predictors of reading comprehension than tasks that merely measure the ability to temporarily store and manipulate meaningless novel information.

The implications for the enhancement of reading comprehension in normal samples is that the focus should be on the improvement of word reading and language skills. Computerised text-to-speech programs, in which children can request the pronunciation of words that they are unable to identify, may be a particularly effective method of improving reading comprehension in children who are past the beginning stages of reading and have no language deficits. Vocabulary enhancement programs may also help to improve reading comprehension skills.

There is very little research comparing the effectiveness of different types of reading comprehension enhancement programs and there is much scope for research in this area. It has been argued that reading comprehension is the key to learning and research in this field would provide invaluable information to parents and educators on the most effective method of improving children’s reading comprehension skills.

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APPENDICES

Appendix 1

TITLE RECOGNITION TASK

Adapted from Cunningham and Stanovich (1990)

Twenty real book titles* and 20 false titles

* Uncanny!	Unexpected!
Blue eggs and tuna	*Northern Lights
Just pretending!	*Possum Magic
Slimy tales	The very awesome Jasmine Jackson
*The elves and the shoemaker	*Wombat Stew
The colonel’s son	*Fox in socks
*Edward the emu	Possum Power
* Go eat worms!	Shark in the dark
* There’s a hippopotamus on our roof eating cake	*Just tricking!
“Don’t dob me in!” and other stories	*The BFG
*Hating Alison Ashley	Alien dawn
The house at Jumping Creek	Big mouth!
*Ark in the Park	Cornelius Fudge returns
Sam and the light-house keeper	*45 and 47 Stella Street and Everything that happened
A voyage to nowhere	*Harry Potter and the philosopher’s stone
The Toymaker	*The voyage of the Dawn Treader
An elephant’s revenge	* Daughter of the regiment
How to be a cool dude in six easy steps	My furry wombat
*Rowan of Rin	Amy goes to New York
* Halfway across the galaxy and turn left	*Gift of the gab

Appendix 2

COUNTING SPAN TASK

TRIALS *(Digits to be recalled in bold***)**

S 13**5**/75**6**	S 57**8**/67**2**/35**1**
1. 68**2**/18**5**	1. 76**1**/95**6**
2. 98**4**/32**8**/78**3**	2. 78**6**/23**5**/12**9**
3. 43**6**/85**8**/79**1**/21**7**	3. 92**6**/56**7**/91**2**/51**5**
4. 57**3**/28**1**/38**4**/19**8**/58**9**	4. 14**6**/83**5**/97**3**/73**8**/75**4**
5. 74**8**/82**9**/97**4**/98**7**/86**1**/76**3**	5. 27**1**/69**4**/31**7**/24**5**/68**3**/65**2**
6. 64**3**/72**6**/85**4**/78**2**/96**1**/86**7**/61**5**	6. 86**8**/95**2**/87**9**/12**4**/71**5**/62**1**/38**7**