Working Memory Performance, Learning and Study Strategies and Learning Styles of Dyslexic and Non Dyslexic Adult Learners

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Abstract

Past research has shown that working memory is a good predictor of learning performance. The working memory processes determine an individuals' learning ability and capability. The current study was conducted to examine the: (a) differences in the working memory performance of dyslexic students in postsecondary institutions, (b) differences in dyslexic students' study strategies and learning styles, (c) differences in the working memory profiles of non-dyslexic university students based on their disciplines (science versus humanities), (d) differences between non-dyslexic science and humanities students in their study strategies and learning styles, (e) relationship between working memory and study skills and (f) hypothesised memory models that best fit the actual data gathered using structured equation modelling technique. Two separate studies were performed to address these aims. For Study 1, a group of 26 dyslexic individuals along with a group of 32 typical non-dyslexic students were assessed for their working memory and study skills performances. A significant difference in working memory was found between the two groups. The dyslexic group showed weaker performance in the verbal working memory tasks which concurs with previous findings. The result also provides support that weakness in the verbal working memory of dyslexic individuals still exist and persist into adulthood. Significant differences in the students' study skills were also identified. Dyslexic students reported to be more anxious and concerned about their academic tasks, lack in concentration and attention, less effective in selecting important materials during reading, using less test taking and time management strategies. Significant relationships were found between working memory component and selected study skills. Study 2 was conducted to investigate working memory differences and study skills of non-dyslexic students based on their disciplines. A sample of 168 university learners consisted of 82 sciences and 86 humanities students were recruited. Analysis of data revealed that students from the sciences disciplines show significantly weaker performance in the verbal short-term memory and verbal working memory tasks. Results from both studies showed similarity in the working memory profiles of dyslexic and science students. Findings in both of the studies with regards to the working memory models and learning and study skills are discussed with practical implications and recommendations for future research.

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Acknowledgements & Dedication

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Author's declaration

I hereby declare that this thesis is the result of my own work. Material from the published or unpublished work of others is credited to the respective author in the text. This work has not been presented for an award at this, or any other, University. All sources are acknowledged as References.

The research referred to in this thesis has been presented at interdepartmental seminars of the department of Psychology of the University of York and at the following conferences:

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CHAPTER ONE

LITERATURE REVIEW

1.1 Introduction

Learning can be defined as changes in behaviours (either via physical, emotion or cognition) and is a continuous and lifelong process. Each individual varies in their ability to learn and differ in their methods of learning. Working memory has been identified as an important factor in learning because of its close relationship with an individual's ability to learn and his/her ability to perform other complex models of cognition (Cowan, 2005; Conway, Kane, & Engle, 2003). Working memory has been acknowledged as a significant part of the cognitive system that supports learning, predominantly during the earlier stages of life. Research indicates that individual's working memory capacity varies among each other. Differences in working memory capacities are reflected in the individual's performance in a various cognitive tasks such as reasoning, acquiring new vocabulary words, reading comprehension and problem solving (Riding, Grimley, Dahraei, & Banner, 2003).

There has been a plethora of studies investigating the relationship between working memory and learning especially when a child enters formal education, where most of the learning process happens (Alloway, 2006; Gathercole & Alloway, 2008; Gathercole, Lamont, & Alloway, 2006; Swanson, Cochran, & Ewers, 1990). Previous research has shown that working memory capacity (Gathercole, Pickering, Knight, & Stegmann, 2004; Alloway, Banner, & Smith, 2010; Riding, Grimley, Dahraei, & Banner, 2003), attention (Fernández-Castillo & Gutierrez-Rojas, 2009) and students' approaches to learning are all important predictors of academic attainments (Kyndt, Cascallar, & Dochy, 2012).

Although numerous past research have been conducted to investigate the relationship between working memory and learning, the bulk of those studies are predominately focused on the working memory capacity and academic performance on typical and atypical development in the early school years. Yet, in the context of postsecondary or tertiary education level, only a limited number of studies have been conducted to investigate the working memory profiles of adult learners to date. This thesis will address this gap in the literature investigating the working memory profiles of adult learners with and without learning difficulties. The main aims are to determine whether there is any difference in the working memory performance of adult learners with and without dyslexia, and whether the working memory profiles are associated with particular study skills, learning styles and subject choices. In each case, I seek to understand the different contributions of working memory (within the context of the multiple-component model of working memory) as a better indicator of an individual's "learning potential".

This first chapter starts with a literature review and a theoretical framework for working memory, followed by an overview of research linking working memory and both learning in typical and atypical children and adults. Studies linking other cognitive abilities such as IQ, study skills and learning styles with learning are also discussed. The chapter closes with an overview of the thesis including the objectives, limitations and synopsis of the studies.

1.2 Working memory: A theoretical framework

The theory of working memory has been of interest to psychologist at the beginning of the 20th century with most of them comparing the memory process inside the human brain with the information processing inside a computer (computer metaphor; this is also the start of a new field of cognitive sciences). A broader view of memory was accepted during the 1960s where it was assumed that information from the environment was first received by our senses (auditory, verbal, visual) before being passed down to a temporary short term memory and finally registered into long term memory. It was therefore assumed to comprise of a set of separate but interconnected information processing subsystem. A particular version of this process was proposed by Atkinson & Shiffrin (1968) which was called a modal model. Atkinson and Shiffrin identified three major storages; the sensory storage, the short term storage and the long term storage. The short term storage was regarded as a working system and a central feature of this model where incoming and outgoing information was being passed through between short term and long term storage.

Although short term storage has a very limited capacity, because of its function mentioned previously, it was considered to be important in learning. However, according to Peterson & Peterson (1959), information in the short term storage rapidly decays and disappeared unless it is being repeated or maintained through sub vocal rehearsal. Thus, the researcher proposed that learning is dependent on the amount of time information is being kept in this temporary storage. Although the theory was simple to understand and make sense, it was subsequently questioned placing too much importance on structure than the process and was found to be too simplistic to explain complex cognitive activities (Figure 1.1).

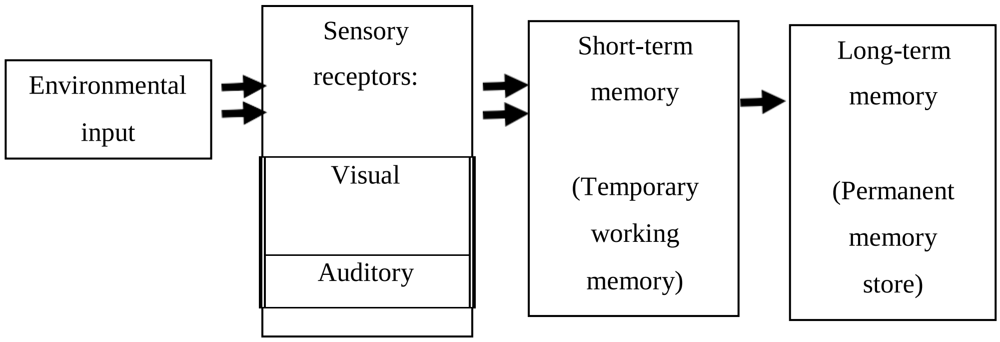


Figure 1.1. The flow of information through the memory system based on the Atkinson & Shiffrin (1968) modal model.

Model of working memory was then brought forward by Baddeley & Hitch (1974) as an alternative to the short term memory proposed by Atkinson & Shiffrin. They argued that short term memory is more than just one simple unitary system. It is suggested that the working memory model comprised of different components that included the modality-free central executive resembling attention and a separate verbal and visuo spatial storage component. The researchers based their argument on empirical evidence through behavioural studies on healthy and brain damaged adults and children. The following section will discuss the differences between some of these memory systems especially on short-term memory, long-term memory and working memory and an elaboration on Baddeley & Hitch (1974) working memory model.

1.2.1 Short-term memory and long-term memory

The term modal model can be traced backed to James (1890) who had distinguished between primary and secondary memory. Short-term memory (or primary or active memory) is the capacity to consciously hold information in the active ready state of mind for very brief period of time (3-20 seconds). Information in short term memory quickly decays or forgotten if not being kept active through sub-vocal repetition called rehearsal or when rehearsal is prevented by distractions between presentation of stimulus and recall (Brown, 1958; Peterson & Peterson, 1959). Thus this memory system is temporary in nature and has a limited capacity in which constrain to 7 plus or minus 2 chunks of information (Miller, 1956) or even lower to 4-5 items (Cowan, 2001). Whereas, long-term memory or secondary memory is unlimited in capacity and the information is kept in the mind as little as a few days or as long as decades (permanent). Information is transferred to long-term memory from short-term memory through the process of rehearsal (Atkinson & Shiffrin, 1968) and meaningful association (Craik & Tulving, 1975). Short-term memory is believed to rely more on phonetic coding than visual coding (Conrad, 1964) while long-term memory more on semantic coding (Baddeley, 1966). There are many types of long-term memory which includes episodic, semantic and procedural memory and will not be discussed in this thesis. Thus, the differences between these two memory systems are mainly in its duration and capacity (Cowan, 2008).

1.2.2 Working memory

Working memory can be defined as an active memory system that is responsible for temporarily holding information while simultaneously manipulating and processing the input before any cognitive decisions is being made (e.g., Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005). It is sometimes refer to as a mental workspace for manipulating activated long-term memory representations (Stoltzfus, Hasher, & Zacks, 1996). Working memory is limited in capacity and a very fragile system in the sense that it requires attention which when distracted or overload could lead to catastrophic loss of information. This is because once information is lost, it is impossible to trace it back again (Gathercole & Alloway, 2008).

Short-term memory is sometimes used interchangeably with working memory. Baddeley and Hitch (1974) believed that the function of short-term memory to be more than just short-term storage as defined by Atkinson and Shiffrin (1968) which prompt them to redefining it in terms of working memory. According to Baddeley (2012), depending on how these two constructs are defined, working memory can be partly distinguished from short-term memory. Firstly, short-term memory passively store information while working memory actively maintain and process information (Baddeley & Hitch, 1974). Next, short-term memory capacity is domain specific (either verbal or visuospatial domain) whereas working memory capacity is domain general (Baddeley, 1986).

In terms of its relationship with learning, working memory has a very strong relationship with academic learning and with other higher level cognitive functions and activities compared to short-term memory (Daneman & Carpenter, 1980; Engle, Kane, & Tuholski, 1999; Kane, Conway, Bleckley, & Engle, 2001). Lastly, short-term memory can operate independently of long-term whereas working memory depends heavily on long-term memory structures. Short-term and working memory measures and tasks that were chosen and administered in the studies in the thesis will reflect these differences.

The next section will describe in detail the most influential working memory model introduced by Baddeley and Hitch's (1974) multi-component model (revised by Badddeley, 2000). This is the memory model that will be used throughout the thesis as a reference when discussing about the influence of working memory on learning on adult learners with and without learning difficulties.

1.2.3 Multi-component model of working memory

The theory of working memory is based on the assumption that a system exists for temporary storing, maintaining and manipulating information simultaneously. By expanding the view of a passive short-term memory to an active system, it provides basis in performing many complex activities (Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005).

The standard working memory model advanced originally by Baddeley and Hitch (1974) and elaborated by Baddeley (1986) comprises of a domain-general component that coordinates information in two separate and independent domain-specific storage components for verbal and visuo-spatial codes (Figure 1.2). The phonological loop is specialised for the temporary storage of information in a phonological form while the visuo-spatial sketch pad is specialized for the temporary storage of information in a visual or spatial forms. These prominent researchers made their argument on the two separate domain specific slave systems based on experimental findings with dual-task paradigms. A person performing a verbal and visual task simultaneously is nearly as efficient if the tasks were done separately. On the other hand, when a person performed two tasks tapping on the same perceptual domain (either two verbal tasks or two visual tasks), performance is less efficient if the tasks were done individually. The domain general component which is the central executive is a limited-capacity sub system responsible for the control of attentional resources as well as between the stores in working memory by constructing integrated multi-modal representations. In 2000, Baddeley added another component, the episodic buffer, which provides an interface between the episodic and semantic memory in long-term memory. Overall, working memory (Baddeley, 1986) is a comprehensive system that unites various short and long-term memory subsystems and functions.

In the present study, Baddeley & Hitch's (1974) multi component model of working memory (see also Baddeley, 2000) will be used as a reference as it has been widely used in both developmental and adult samples (e.g., Alloway, Gathercole, Willis, & Adams, 2004; Baddeley, 1996) of memory studies. The following sections will explain each components of working memory model and experimental findings related to it. Figure 1.2 illustrated the working memory model as proposed by Baddeley & Hitch (1974) including the episodic buffer component (Baddeley, 2000).

Phonological Loop (PL)

The phonological loop is responsible for storing and maintaining information in a phonological form either from auditory verbal stimulus (Baddeley, 1986, Baddeley, Gathercole, & Papagno, 1998) or from visual presented information (after being transformed into phonological code via silent articulation) (Gilliam & van

Kleeck, 1996). It comprises two components: a passive short-term phonological store which holds auditory memory traces that rapidly decays, and an articulatory rehearsal process that can reactivate the memory traces equivalent to sub-vocal speech.

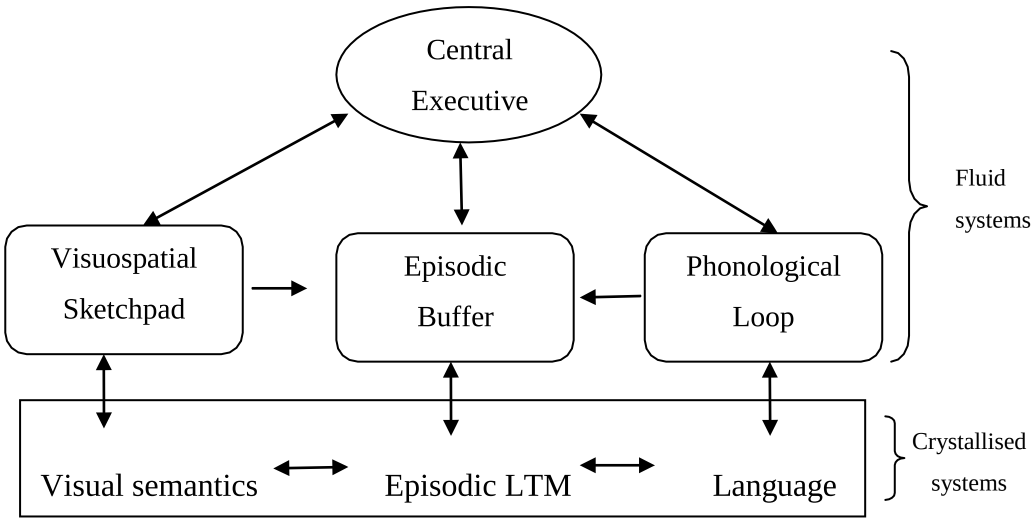


Figure 1.2. Multi-component working memory model with links to long term memory, based on Baddeley (2000).

Verbal information that is presented orally will gain direct and immediate access to the phonological loop and stored in phonological form (Hitch, 1990). Phonological loop also transforms perceptual stimuli into phonological codes that will then be matched with existing codes such as phonemes and words which were stored in long term memory. Meaningful representation from long term memory will also be used when trying to understand a sentence or a story. This high level activity involves complex working memory functions that are carried out by the central executive (Dehn, 2008).

The characteristics of the phonological loop described here build upon evidence from key experimental phenomena including the phonological similarity and word length effects. The similarity effect is the poorer recall of list containing phonological similar items (e.g., cap, slap, trap, map) than those that are phonologically distinct (Conrad & Hull, 1964; Baddeley, 1968; Copeland & Radvansky, 2001). In addition, the word length effect experiments have shown that the amount of information that can be maintained in the verbal short-term storage (approximately in 2 s) will depend on the quality and quantity of articulation of an individual. Longer words were assumed to take longer to rehearse thus resulting in more trace decay and poorer recall (Baddeley, 2007). Those individuals who have faster articulation rates can maintain more items than individuals who are much slower in their articulation (Baddeley, 1986; Baddeley, Thomson & Buchanan, 1975; Hulme & Mackenzie, 1992). However, both effects can be eliminated by preventing rehearsal using an interference task: specifically, articulatory suppression. This typical interference task require the participant to engage in concurrent speech such as "the, the, the …" while performing a verbal tasks. The articulatory suppression provides evidence of the importance of rehearsal in short-term retention of information (Baddeley et al., 1975).

The serial recall paradigm informed the development of the concept of the phonological loop and is typically measured with a simple digit or word span tasks. These tasks require an individual to read and remember a list of digits or words that were presented to them. The length of the longest list a person being able to remember is their digit span. Whereas, verbal working memory is typically measured using tasks that both taps on storage and processing functions of working memory such as the listening or reading span tasks developed by Daneman and Carpenter (1980).

Various studies have investigated verbal span and found that verbal working memory to be incredibly robust with high predictive relationships with cognitive functioning, academic learning and everyday tasks. For example, an important contribution of the phonological loop based on empirical evidence is that it might act as a language learning device in the acquisition of vocabulary, particularly in the early childhood years and for learning a second language (Baddeley, Gathercole, & Papagno, 1998 ; Papagno, Valentine, & Baddeley, 1991). For typical adults, phonological memory span has been assumed to be approximately seven units

(Miller, 1956). The measures of verbal working memory will be explained in detail later in the following sections.

Visuo spatial Sketchpad (VSSP)

The visuo-spatial sketch pad is the second short term storage component of the working memory model and is responsible for temporary storage, maintaining and manipulation of visual and spatial information (Baddeley, 2006). Similar to the phonological loop and based on previous experimental findings, Logie (1995) proposed that VSSP consists of 2 subcomponents: one act as a passive storage system for visual and spatial presented stimulus while the other as an active rehersal mechanism for both visual and spatial information (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999; Repovs & Baddeley, 2006).

The VSSP component was found to play an important function during reading, it maintains the visuospatial frame of reference when a reader visually encode printed letters when reading so that the reader can backtrack and know where he is in relation to other letters or words as he moves through the passage (Baddeley, 1986). Reading includes automatic processing such as letter identification, semantic information (pictures, texts or diagrams) and text elaboration. An important point to take note is that visuospatial storage and rehearsal depend on phonological loop and articulatory rehearsal. Individuals who are 10 and above, typically verbalised visuospatial information (e.g., location and objects of to be remembered items). Older children are able to recode visually presented materials into speech-based form due to the automaticity of reading (Hitch, 1990; Richardson, 1996). However, visually presented item that is difficult to name will be encoded visually and may prevent rehearsal and thus affect retention (Baddeley, 2003).

Therefore, based on the current research on VSSP, it is regarded as a component divided into a visual and spatial sub-parts each with its independent storage, maintanence and manipulation processes. Although research evidence has shown that tasks which taps on VSSP depends heavily on the central executive (Alloway, Gathercole, & Pickering, 2006; Gathercole & Pickering, 2000b), it seems that only manipulation depends on executive resources while maintenance seems to be independent of it (Klauer & Zhao, 2004 and Bruyer & Scailquin, 1998 as cited in Repovs & Baddeley, 2006).

Central Executive

In contrast to the phonological loop and the visuo-spatial sketch pad, the central executive does not involve any storage. Much of Baddeley's work on the central executive has employed concurrent tasks such as the backwards digit recall tasks that able to separate the three initially proposed working memory subcomponents (Baddeley, Allen, & Hitch, 2011). The task was created on the assumptions that it will disturb the various components of working memory where the attentionaly demanding task will place specific demands on the central executive, in contrast with task that only require maintenance.

Baddeley (1996) proposed and identified the following functions of the central executive based on several experimental studies; the ability to focus (Baddeley, Emslie, Kolodny, & Duncan, 1998), the ability to divide (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991) and to switch or select attention and plans (Allport, Styles, & Hsieh, 1994), and the ability to link the content of working memory to long term memory (temporary activation of long-term memory) (Baddeley, 2000, 2012). The latter function associated with the central executive has been subsequently reassigned to a new component of working memory, the episodic buffer which will be mentioned next.

Episodic Buffer

The latest addition to the working memory model is the episodic buffer which was added to fill a gap where neither the phonological loop, visuo-spatial sketchpad, nor the central executive can be regarded as general storage that can combined several kinds of information (Baddeley, 2000). In an attempt to constrain the working memory model, Baddeley & colleague assume the central executive to be a purely attentional system with no storage capacity (Baddeley & Logie, 1999). However, this assumption has created several problems and questions. Various findings were hard to account for without the episodic buffer in the working memory model for example in explaining the numeral advantage in memory span between

Arabic numerals and digit words (Chincotta, Underwood, Abd Ghani, Papadopoulou, & Wresinski, 1999) and development of working memory for verbal-spatial associations (Cowan, Saults, & Morey, 2006). Therefore, Baddeley & Wilson (2002) have identified several characteristics of the episodic buffer which includes a limited capacity storage, ability to integrate information from a range of sources into a single complex structure, and acts as an itermediary between the two slave subsystems (PL & VSSP), and combining them into a unitary multi-dimensional representation. Overall, the episodic buffer can be regarded as a fractionation of the central executive since some functions previously assigned to the central executive are now assigned to the episodic buffer (Baddeley, 2006). This perspective has recently been extended to link emotion with episodic buffer function (Baddeley, 2007).

The Baddeley and Hitch (1974) working memory model has been exerted a great influence on the field of working memory research for over the last three decades and remains one of the leading models in the field. After more than three decades of extensive research, it has been evident that working memory is not a single store but a memory system that comprises of separate multiple components. These components maintain and process information during demanding cognitive activities and operate as a temporary link between external and internal generated mental representations.

Nevertheless, the theory of working memory will further developed and changed over time with different researcher holding different theories to explain the same data. Although the work reported in this thesis was guided specifically by the Baddeley and Hitch (1974) working memory model, there are several other important models of memory that are reviewed below.

1.2.4 Alternative models of working memory

Working memory theory is a contentious theory where there are several different views or different theoretical framework being offered to explain this memory component. There are several discussions on whether working memory is best understood as a specific capacity (or set of capacities) or a combination of attentional processes and processing ability in particular domains. One influential approach to working memory is Nelson Cowan's embedded processes theory. Cowan described working memory as "cognitive processes that retain information in an unusually accessible state" (Cowan, 1999 p.62). In this theory, he distinguished between a subset of long-term memory that is activated above some threshold and a subset of this activated memory which is the focus of attention or conscious awareness. The activation is temporary and decays if not maintained either through active verbal rehearsal or continued attention. The activated memory is multidimensional which resembles episodic buffer in Baddeley's (2000) working memory model, however Cowan's interest is more on the focus of attention that is controlled at least partly by the central executive (Cowan, 1997) and he strongly argues for a capacity of 4-5 items (Cowan, 2001, 2005) that can be held in the focus of attention at any one time compared to 7 items as proposed by Miller (1956). Figure 1.3 shows Cowan's working memory model.

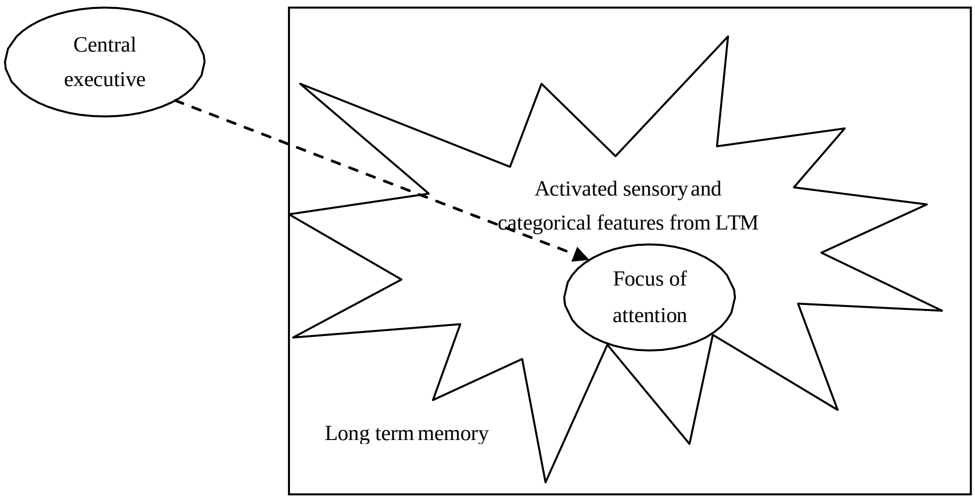


Figure 1.3. Cowan's embedded-processes model of working memory with the central executive controlling the focus of attention which holds approximately four objects in mind at one time. Adapted from Cowan (1988).

Another approach to working memory has been developed by Engle and colleagues. They work focused on the theoretical issues of understanding what the capacities and processes underlying associations between working memory span and various cognitive capacities. Their work focused on the power of the general construct of working memory capacity for individual differences. Engle has argued that working memory capacity is the same as central executive ability, controlled attention and general fluid intelligence (Engle, Kane, & Tuholski, 1999). More specifically, it has been proposed that individual difference based on working memory capacity mainly reflect difference in capability for controlled processing and reflect the ability to apply motivation to memory representation to either bring them to focus or maintaining it especially in the face of interference or distraction (Kane, Conway, Hambrick, & Engle, 2008).

While Engle and colleagues argued that the crucial feature of working memory is maintaining attention against distraction, an alternative argument is the possibility of preventing decay through rehearsal by constantly focusing attention on the fading trace which was proposed by Barrouillet, Bernardin and Camos (2004) time-based resource sharing model (this model was mainly developed and tested on adults). They argued that a complex task allows brief gaps so that rehearsal might occur while simple task minimizes rehearsal since it is rigidly controlled. Nonetheless there is a common agreement between these models where they assumed that working memory acts as a form of mental workbench, providing a space for thought, having a strong link between working memory and attention, and the ability to draw on other resources within short term and long term memory (Miyake & Shah, 1999).

Various researches on working memory in typical and atypical learners found well established relationship between working memory with reading comprehension ability and math ability (Swanson, 2011; Archibald & Gathercole, 2006; Pickering, 2006). Empirical evidence showed that reading or math disability reflects a fundamental deficit in the development of working memory. The theoretical explanation in terms of the structure and functional role of working memory behind the data can be explained in either of these two ways. Based on the original Baddeley and Hitch (1974) working memory model, some researchers argued that the relationship between working memory performance and reading or math abilities depends on the task demands which also refer to domain-specific constraints (the inefficiency in accessing phonological representation or verbal information). Other researchers argued with reference to domain-general constraints (capacity limitations or dependency on the attentional resource or central executive control component of working memory) in explaining the involvement of working memory in reading or math performance (Engle, Kane & Tuholski, 1999; Turner & Engle, 1989). As a matter of fact, evidence has shown that tasks that involve maintaining and manipulating information simultaneously or tasks that involve executive functions, regardless of task modality, correlate more strongly with reading ability than storage-only tasks such as short-term memory tasks (Daneman & Merikle, 1996).

Carretti, Borella, Cornoldi and De Beni (2009) did a meta-analysis study investigating 18 research on individual differences in working memory and reading comprehension. Carretti and colleagues's examined the relevance of several working memory measures in differentiating between high and low reading comprehenders in relation to the modality of the working memory task, and the influence of attentional or executive control in performing the tasks. Their findings confirm that working memory tasks that involve a high demand in terms of attentional resources are a better predictor of reading comprehension performance than measures of simple span tasks (Daneman & Merikle, 1996). The result thus appear to support the non-unitary models of working memory (Badddeley & Logie, 1999), suggesting that deficits in reading comprehension by poor comprehenders can also be explained partly by the inefficiencies in working memory control mechanisms, which are failing to support specifically the verbal processing (Swanson & Berninger, 1995).

Swanson (2011) argued that based on their empirical research and evidence on the influence of working memory on reading and math performance in children with math and/or reading disabilities, depends on task demands and can either be related to domain-specific constraint or domain-general constraint. Swanson's team of research also based their thoretical framework on Baddeley and Hitch (1974) multicomponent working memory model to explain working memory performance in children with math and/or reading disabilities. In a study conducted by Swanson and Berninger (1995) where they investigate whether verbal working memory and verbal short-term memory accounted for the different cognitive profile of children with reading disabilities. The children were divided into four groups based on their reading abilities: High Comprehension/High Word Recognition, Low

Comprehension/Low Word Recognition, High Comprehension/Low Word Recognition, and Low Comprehension/High Word Recognition. Their results showed the working memory deficits to be reflective of the poor comprehension-only group and the short-term memory deficits were reflective of the poor-recognition only group. They concluded that the executive processing problems exists in children with reading disabilities independent of their deficits in the phonological processing. Their other research comparing subgroup skilled and children with reading disabilities on various executive processing, phonological, visuo-spatial and semantic tasks support domain-general deficits where the impaired capabilities for controlled processing appears to manifest accross verbal and visuo-spatial working memory tasks (Swanson, 1999; Swanson & Sachse-Lee, 2001). Examples of central executive processing deficits may include the inability to maintain task relevant information while ignoring distractors or interference, the inability to suppress irrelevant information to focus on task and inability to access information from long term memory. However, Swanson also argued that although the deficits in the central executive could be domain free, they can, based on the type of task and processing demands, reflect domain-specific codes (Swanson, 2011).

Referring to these various approaches and explanation of working memory models, the thesis offer predictions or ways of thinking about the central thesis work. In line with a domain-specific view of working memory, it is possible to predict that, if relationship between working memory and performance is mediated by task modality and attentional control, then verbal complex memory tasks should better discriminate the performance between dyslexic and non-dyslexic (or between science and humanities students) than verbal simple memory tasks and visuo-spatial tasks. In contrast, a domain-general view of working memory should predict that working memory tasks, regardless of task modality, should better capture the differences between dyslexic and non-dyslexic (or between science and humanities students) compare to less demanding tasks in terms of attentional resources such as short-term memory tasks.

1.2 Working memory measurement

Much of the research mentioned previously is based largely on dual task experiments and on neuropsychological evidence. This approach has provided valuable information about the fractionation of working memory into independent stores and processes, the nature of representations in individual stores, the mechanisms of their maintenance and manipulation, the way the components of working memory relate to each other, and the role they play in other cognitive abilities (Repovs & Baddeley, 2006). Baddeley's multi-component approach of working memory and the distinctions it makes between several cognitive domains has always prove to be particularly useful in analysing tasks demands as well as individuals' specific impairments. Hence much of the research will be based on this multi-component working memory model. The experiments completed in this thesis focused on understanding how different components and structures of working memory were able to separate or discriminate individuals in terms of learning difficulties or disciplines/interest. We will also investigate the relationship between working memory components with other cognitive abilities and learning skills that has been adopted by these students.

There are now well established measures to access each component, except the episodic buffer (which is still an important area to research in). Each different working memory component is measured using different tasks/assessment. Measures of short-term memory are noticeably different from measures of working memory, however both short-term and working memory are related with one another (St Clair-Thompson, 2010). The next few sections will provide an overview of how each component of working memory based on Baddeley and Hitch's model is measured and assesses.

1.2.1 Measures of verbal short term memory

Short-term memory is commonly assessed using tasks in which participants were give lists of items and asked to recall the items in sequence. Below are examples of the verbal short-term memory tasks.

Serial recall

The phonological short term memory is typically assessed using serial recall where individuals are asked to recall a list of verbal items in the same correct order after the presentation of stimulus. The lengths of items to-be-remembered increases until the point at which recall errors are made. Memory span is the longest list of items that an individual can recalled accurately in sequence. This is a common measure of short term memory and may include words, digits, or letters. The typical serial recall tasks are digit span or word span recall (Gathercole & Pickering, 2000a; Pickering & Gathercole, 2001) and primarily taps the phonological loop requiring little support from the central executive.

Non-word repetition

Another method to measure the phonological short-term memory is through a non-word repetition task. A participant has to remember a list of non-words which is an unfamiliar phonological sequence that matched the phonotactics rules of the participant's native language. For example '*nop jitch garm'* are monosyllabic words with a consonant-vowel-consonant structure and the participant has to repeat the words in sequence as accurately as possible. The ability to repeat non-words has been linked to the ability to learn the sounds of new words. Children who performed well in digit span and non-word repetition showed good vocabulary achievement, even when other factors such as age or general intelligence has been factored out (Gathercole & Baddeley, 1989; Gathercole, Service, Hitch, Adams, & Martin, 1999; Gathercole, Willis, Emslie, & Baddeley, 1992). Substantial evidence from earlier research has also shown this link between non-word repetition with word learning in typically developing children and adults (Gupta, 2003) as well as those with learning disabilities such as those with Specific Language Impairment (SLI) (Gathercole, 2006) and down syndrome (Comblain, 1999). These findings from different participant groups and methodologies supports the interpretation that non-word repetition task largely reflect capacity of the phonological storage.

Non-word repetition task is an example of a purer measure of short-term memory abilities than the above classic memory span tasks (e.g., digit span and word span). It was argued that there is minimal lexical support from long term memory for non-word repetition task than serial recall, in which familiar verbal items are used, making this subtest a highly sensitive measure of phonological short-term memory (Gathercole & Pickering, 1999).

1.2.2 Measures of verbal working memory

Working memory is usually assessed using tasks where participants were requested to recall the given items in sequence while engaging in a processing activity which is interleaved between the memory items. Below are examples of verbal working memory tasks.

Backwards digit recall

Backwards digit recall task is administered in exactly the same way as the Digit recall subtest except participants were asked to recall the series of digits in the reverse order. The task is different from short-term memory task because of the requirement to reverse the order which acted as a processing activity.

However, there have been many debates whether backwards digit recall should be considered as working memory task or a short-term memory task. This is because backwards digit recall has also been used within research as a measure of short-term memory in adult participants (Engle, et al., 1999) as well as measure of working memory in children's study (Gathercole, Pickering, Ambridge, & Wearing, 2004). St Clair-Thompson (2010) suggested that backwards digit recall can best be described as measure of working memory in children, however as a measure of short-term memory in adult participants. A series of confirmatory factor analysis (CFA) were conducted using her data of children and adult participants in both short- term memory and working memory tasks which include the backwards digit recall task. Her findings showed that in children, Model 1 where backwards digit recall was loaded on to the working memory factor provided an excellent fit for the data. Whereas, with the adult data, Model 2 provided an excellent fit (backwards digit recall was loaded on to the short-term memory factor).

One explanation suggested by St Clair is based on the individual differences and strategies adopted to perform the same task given in her research. In children, reversing a digit sequence might require the central executive attentional resources whereas for adults the task might be less attention demanding drawing only on the short-term memory resource. For high ability participants, reversing the sequence of digits could be a routine task that is determined by the storage capacity and not processing efficiency (Bayliss, Jarrold, Gunn, & Baddeley, 2003). However, other research have also found that adults with lower memory capacity such as adult dyslexic or older adults shown a significantly lower scores in backwards digit recall compared to normal readers or typical adults with no learning difficulties (Fostick, Bar-El, & Ram-Tsur, 2012; Sela, Izzetoglu, Izzetoglu & Onaral, 2012). Investigating the difference between backwards digit recall and measures of short-term memory and working memory in different adult populations would be examined and discussed in this thesis.

Listening recall

Another commonly used task to measure verbal working memory is listening recall or listening span. This task is referred to as "complex span" task where participant performed an additional processing task while maintaining new information. It is in contrast to "simple" span task that require participant to just encode and recall information immediately. This task is an extension from a reading span task which is originally developed for use with adults by Daneman & Carpenter (1980). For listening recall task, participant will be asked to listen to a series of spoken sentences and remember the final word of each sentence. The task is made more complex by inserting a processing task typically involving a verification question, which the participant must answer before listening to the next sentence. For example, the sentence might be "The sun is cold" followed by "Is that true?" This task is demanding even for adults especially when it reaches to trials with more than three to four sentences. Therefore listening recall task measure the important aspect of working memory functioning in terms of the ability to store and process information simultaneously in the immediate memory (Pickering, 2006b).

1.2.3 Measures of visuospatial short-term memory and working memory

While verbal memory tasks usually involve listening to orally presented materials, visuospatial short-term memory on the other hand is assessed using tasks in which participants are presented with visual-spatial stimuli such as a red path in a 2-D maze or a red dot in a 4x4 matrix with participant having to recall the exact route shown in the trial or recalling positions of the red dots on the appropriate squares (Alloway, 2007; Pickering & Gathercole, 2001). However, older children or adult tend to recode visual information into words. By the age of seven, children will increase in their awareness of using memory strategies in learning especially when their level of language skills also increases (Gathercole & Alloway, 2008). This is when children start to use more verbal rehearsal and thus shift their strategies to remember information in terms of verbal characteristics if possible rather than visual (looking at it). Therefore, visual-spatial stimuli were selected on the basis of being very difficult to recode verbally, thereby reducing the influence of verbal working memory.

Visuospatial working memory on the other hand, is assessed by using tasks in which participants have to engage in a processing activity which is interleaved between the memory items. Examples of visuospatial working memory tasks are the Odd-one-out, Mr. X and Spatial span tasks. All three of these subtasks present a processing task together with a remembering task which therefore considered as complex visual span tasks. These subtasks are also suggested to measure visuospatial working memory based on a factor analysis study by Alloway et al. (2006), where the researchers found these subtasks to tap on executive working memory process as well. Next section will explain the computer based assessment used in the thesis to measure working memory components both verbal and visuospatial.

1.2.4 The Automated Working Memory Assessment (AWMA)

AWMA (Alloway, 2007) is a computer based assessment of working memory skills that was developed based on the well-researched Baddeley & Hitch (1974) working memory model. It was designed to identify and screen individuals between 4 (early childhood) and 22 years of age (adulthood) for significant working memory problems. The AWMA was an extension from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) with some modifications to the subtests. The long form consists of 12 subtests which includes 3 measures for each of verbal and visuospatial short term and working memory. In line with previous empirical testing, verbal and visuospatial short term memory were assessed using tasks involving storage information only, while verbal and visuospatial working memory were measured via tasks involving both storage and processing information. Alloway (2007) has abandoned the notion of a general domain of working memory in Baddeley's theory by separating it into verbal and visuospatial working memory. However, the researcher also confirmed via a confirmatory factor analyses in a large scale study that the multiple tasks measuring the four different memory components reflected the Baddeley and Hitch (1974) three-component working memory model (Alloway, et al., 2006) where the processing aspect of both the verbal and visuospatial working memory tasks was controlled by a centralised component while the short term storage aspect was supported by a domain-specific component (phonological loop for the verbal information while the visuospatial sketchpad for the visuospatial information).

Children who scored poorly on AWMA were associated with poor academic achievements and learning outcomes especially in their performance in the national curriculum assessments in English, Maths and Science (Alloway, 2008; Alloway, Gathercole, Adams, & Willis, 2005; Alloway, et al., 2005; Alloway, Gathercole, Kirkwood, & Elliott, 2008; Alloway, Gathercole, Willis, & Adams, 2004). AWMA was also shown to provide nonbiased measures of cognitive abilities without being influence by socio-economic factors (Engel, Santos, & Gathercole, 2008). The assessment was also found to reflect similar findings in working memory profiles of clinical and prevalent developmental disorders such as those with dyslexia, Specific Learning Impairment (SLI), Developmental Coordination Disorder (DCD), Attention Deficit Hyperactivity Disorder (ADHD) and Autistic Spectrum Disorder (ASD) especially in mainstream education with an impact in academic progress (Alloway & Archibald, 2008; Alloway, Elliott, & Place, 2010; Alloway & Gathercole, 2006; Alloway, Rajendran, & Archibald, 2009).

1.2.5 Summary

Overall, there are many different methods to measure verbal and visuospatial short-term memory and working memory. Since one of the main objectives of the thesis is to investigate the working memory profiles of adult learners with and without learning difficulties, selected subtests from the Automated Working Memory Assessment and other cognitive tasks were chosen to identify participants' strength and weakness in the working memory components. The importance of identifying an individual's working memory profile is to increase the learner's awareness of his cognitive ability in any learning environment or situations. Thus, the individual can maximise his/her learning by developing effective strategies that will be able to compensate for any areas of working memory weaknesses. There are numerous well known and documented evidences that have shown links between working memory and learning and will be presented and discussed in the next section.

1.3 Working memory and learning

With the definition of working memory as a workbench where information is held and process over brief periods of time during ongoing cognitive activities, it is therefore evident that it is one of the important cognitive abilities in learning. Nearly all that is learned have to pass through working memory. Recent research indicates that working memory play a key role in helping the mind focus and screen out distracters (Drew & Vogel, 2009; Fukuda & Vogel, 2009). There are many learning activities in the classroom where children have to hold information while engaging in effortful activities such as following directions and instructions, sustaining attention, doing complex reasoning or even copying a sentence from the class board. Working memory is required when a student is asked to copy sentences or instructions; he/she had to write them while trying to spell the individual words and carrying out individual steps in the task.

Hence, it is an advantage when researcher found links between working memory with learning and academic performance so that teachers, practitioners in education and policy makers be able to provide support for students' learning. The following sections will discuss and provide evidence for this strong relationship between working memory and learning in children as well as in adults.

1.3.1 Working memory and learning

Working memory develops across the childhood years through adulthood with a dramatic increase in the first 10 years of life and steadily increasing until it reaches plateau between 25-30 years of age. The average five-year-old can hold one item in mind, while a seven-year-old can remember two items, a 10-year-old can remember three items and a 14-year-old can remember until 4 items at a time (Gathercole, et al., 2004). Working memory skills can explain individual differences in learning which mainly arises from its limited capacity. Hence the capacity and effective functioning of working memory determines the rate and extent of learning (Pickering, 2006b).

There has been a numerous research investigating working memory performance in children and adults and linking working memory with academic attainment. Recent findings in this area indicated that working memory is a good predictor in academic performance and academic attainment during school years (Gathercole, Brown & Pickering, 2003; Jarvis & Gathercole, 2003; Gathercole & Alloway, 2008; Alloway & Alloway, 2009). Working memory assessment has also been suggested to be a much better predictor of academic success than IQ. Alloway (2009) did a longitudinal study on children's academic achievement and working memory and IQ at 5 years old and again 6 years later. The findings indicated that a child's success in all aspects of learning depends on how good their working memory is regardless of IQ score (Alloway & Alloway, 2009). Hence, the better the child's working memory skills the better they will perform in school, while weakness in working memory is strongly associated with impairment in learning especially in reading, comprehension and mathematics (Gathercole & Alloway, 2008).

Research done in schools showed that working memory performance is likely to predict future academic attainment of school children as early as 4 years old (Alloway, et al., 2005; Gathercole & Pickering, 2000b). Survey done on over four thousand children, found that ten to fifteen percent of school children across all ages suffer from poor working memory seriously affecting their learning. Although there is a steady development in working memory capacity during childhood years, there is a large individual difference that exists between children of the same age. Those who scored within or below the ten percentile in working memory tasks at the age of 8, have the same average score with children at the age of 5, whereas those in the ninety percentile have the same scores as children aged 13, indicating that those with poor memory functions earlier in their school years will often compromising learning and scholastic achievements in future (Gathercole, 2002; Alloway, Gathercole, Kirkwood, & Elliott, 2009).

Why is working memory so crucial for learning? Classroom performance and the development of verbal and academic skills such as reading decoding, reading comprehension, mathematics, and written expression, depends heavily on the adequate functioning of working memory. The strong relations between specific areas of academic achievement and short term and working memory components are well established (Swanson, 2000; Swanson & Berninger, 1996). In typical classroom learning environment, continuous, heavy demands are placed on working memory (Alloway & Gathercole, 2006; Gathercole & Alloway, 2008; Gathercole, Lamont & Alloway, 2006). Many classroom learning activities involve both simultaneous demands on storage and processing information. Children with small working memory capacities or having working memory difficulties will struggle and often fail in such activities. Examples of the activities include listening to a speaker while trying to take notes, following complex instructions, decoding unfamiliar words, writing sentences from memory, and mental arithmetic. One of the explanations would be that the working memory acts like a bottleneck for learning (Gathercole, Lamont, & Alloway, 2006). The assumption that working memory act as a workbench that function as a holding store while information is being further process or manipulated is important especially in reading development (Swanson, 1999; Swanson & Sachse-Lee, 2001). Effective learning requires new information to be processed and integrated with previously stored knowledge or information, and thus materials need to be maintained across critical periods of the learning activity. Poor capacity to hold such information in working memory will therefore jeopardize subsequent learning success and this is the reason why children with poor working memory typically fail to learn subsequently making poor general academic progress (Gathercole & Alloway, 2008). Even for those with normal working memory capacity and functioning, the working memory demands of classroom instructions and learning activities can be excessive at times, leading to task failures.

Common profiles of children with working memory impairments have sometimes being misdiagnosed or typically being reported by teachers as being lazy, inattentive, or having low intelligence. Although these children are seen as well-adjusted socially, they seem reserved in group activities, behaving as not paying attention, lost track of activities and forgetting instructions. The evidence fits well with recent research which shows individuals with low working memory capacity were much more likely to engage in mind wandering or called as "zone out" when performing demanding cognitive activities (Kane, et al., 2007). These are some of the characteristics associated with working memory impairment for the teachers to spot earlier so that they can work hand in hand with these children to improve working memory thus increasing the chances of success in the classroom. Teachers can then adapt their teaching methods to help children's learning before they fall far behind their peers (Alloway, 2011; Gathercole, et al., 2008).

There was however less study done on the impact of working memory weaknesses on learning performance in adult learners especially those in postsecondary institutions due to the fact that these learners have managed to wiggles their way through primary school that they might be overshadow by those students who have been identify having learning difficulties early in their school years. Nonetheless, research in neurodevelopmental disorders and other learning difficulties associated with learning in children and adults have found links with working memory impairments which will be discussed next. It is hoped that the studies conducted in this thesis will contribute to new knowledge of working memory profiles of adult learners in higher education.

1.3.2 Working memory and learning disabilities/difficulties

Learning disabilities or learning difficulties refer to individuals who have specific problems in acquiring knowledge and skills to the level expected of those of the same age, especially when it is not associated with a physical handicap (Hulme & Mackenzie, 1992). Those with learning difficulties may also have problems with acquisition, organization, retention, understanding or use of verbal and nonverbal information (Swanson, Harris, & Graham, 2003), however demonstrate at least average abilities for thinking or reasoning/intelligence (having average or above average IQ).

Many educators and psychologists acknowledge that individuals with learning difficulties are likely to have deficiency in one or more cognitive processes (Masoura, 2006), including phonological processing, auditory processing, long term retrieval, attention, short term memory, and working memory. Since low working memory capacity and impairments have been associated with deficits in learning, working memory problems have also been identified as key features of many learning difficulties and developmental disorders including specific reading difficulties (Pickering, 2006a), dyslexia (Jeffries & Everatt, 2004), language impairments (Archibald & Gathercole, 2006; Isaki, Spaulding & Plate, 2008; Alloway & Archibald, 2008), mathematics disorders (Zimmermann, 2008), and attentional problems (Gropper & Tannock, 2009; Roodenrys, 2006).

Research has shown that children with learning difficulties are four times more likely to exhibit behaviours associated to working memory impairments. Individuals with general or multiple specific learning difficulties (literacy and mathematics) performed poorly in all aspects of working memory. Those with only one specific learning difficulty demonstrate fairly distinctive working memory profiles with deficit limited to one or two components. For example, children with specific reading disability frequently have impairments in phonological short-term memory and verbal working memory (Pickering & Gathercole, 2004), whereas children with specific mathematics disability tend to have deficits in visuospatial and executive working memory (Bull & Espy, 2006). Therefore, these studies suggested that there are different working memory profiles associated with a range of learning difficulties and genetic disorders (Alloway & Gathercole, 2006; Barrouillet & Gaillard, 2011). Working memory profile is an individual's particular strength and weaknesses across different sub-component of working memory (Baddeley & Hitch, 1974).

Research investigating working memory profiles of children with language and reading difficulties, reported deficits in their verbal short term and verbal working memory (Archibald & Gathercole, 2006; Pickering, 2006a). Individuals who were identified as having difficulty in the area of reading (literacy) or language processing such as those who have dyslexia, tend to show a working memory profile with weakness in their central executive and phonological loop (verbal working memory) while maintaining their visuospatial sketch pad (Pickering, 2006a; Isaki, Spaulding, & Plante, 2008). Whereas individuals who have Attention Deficit Hyperactivity Disorder (ADHD) with attention and hyperactivity problems or Dyspraxia (motor co-ordination problems) show a different working memory profile where their weakness is more on the visuospatial sketch pad with a good phonological loop component of working memory (Roodenrys, 2006; Jeffries & Everatt, 2003). Recent study have also compared the working memory functioning of deaf children, children with ADHD and typically developing children where their findings showed that deaf children and children with ADHD share similar working memory profiles, implying that it will be easier to accommodate both sets of children together in an inclusive classroom (Cockcroft & Dhana-Dullabh, 2012).

However, not all findings on working memory performance were consistent with each subtypes of learning difficulties. Research by Swanson & Berninger (1996) has consistently found children with all types of learning difficulties to display poor working memory performance, especially in verbal and executive working memory. A pilot study done by Gropper and Tannock (2009) on college students with ADHD found that although there was evidence of working memory impairments in this subgroup (students entering university with ADHD) compared to normal control, they displayed significant weaknesses on auditory-verbal working memory tasks rather than a visual-spatial working memory tasks found in previous studies in children with ADHD. The researcher speculated that the inconsistent findings are attributed to difference in methodology or the comorbidity with learning disabilities.

There are about 5.6% of total full-time students with a specific learning difficulty entering higher education in 2011/2012 in the U.K (Higher Education Statistic Agency, 2013) with students reported being dyslexic representing the largest disability category in higher education, and many of these were identified after entry. With the increasing number of students with learning difficulties including dyslexia; dyspraxia as well as ADHD entering tertiary institutions such as colleges and university, this issue is becoming increasingly important. This is due to the fact that most researchers focused their studies on working memory and learning on children during their primary school years where learning is much more structured.

Although few empirical studies has been conducted on working memory and adult learning within the higher education community, the working memory abilities of adult learners with learning difficulties have not yet been the subject of extensive study (Cohen-Mimran & Sapir, 2005; Gropper & Tannock, 2009; Jeffries & Everatt, 2003; Smith-Spark & Fisk, 2007; Swanson, et al., 2003). The first study in this thesis will explore the working memory performance of students in postsecondary institutions with and without dyslexia. The next section will discuss more on the definition of dyslexia and the various theories that help to explain and understand this hidden learning disability from various points of view.

1.4 Dyslexia

Dyslexia is one of the most commonly researched learning difficulties affecting 3-6% of children, with boys being affected more than girls (Rutter, Caspi, Fergusan, Horwood, Goodman, Maughan, et al., 2004). It is a worldwide phenomenon where children with average or above average intelligence have a hidden disability where they are unable to read thus affecting their academic performance in schools. Findings from the National Center For Educational Statistics showed nearly 40% of the students in America are reading below the basic level of proficiency (as cited in Denton, Fletcher, Anthony, & Francis, 2006). In the United Kingdom, 10% of the children are dyslexics (Dyslexia Action, 2012), where 1 in 8 fail to master basics of reading, and 1 in 5 fails to master the basics of writing at the end of primary school (Department for Education, 2012). The numbers show about 1.2 million children struggle with literacy and being identified as dyslexic. At the secondary level, over a third of young adults failed to achieve A+ to C in English in 2011 (Jama & Dugdale, 2012).

At the university level, dyslexia is an important issue of discussion because of the rising numbers of students disclosing it as their learning difficulty. A 30% to 40% increase in the number of students in the university reporting having dyslexia from 2007 until 2012 were reported by HESA (cited in Elliot & Grigorenko, 2014). Typically, students can obtain diagnosis of dyslexia through a paid educational psychologist or specialist undertaking an assessment which could be very expensive. Based on the assessment report, students can request from their university certain allowances (Disable Students' Allowance) such as special assistance tools or even additional time in examinations to support their learning (Walton, 2014). Therefore, a scientific diagnosis of the term is needed. However, the problems arise when there is no consensus between the researchers in the definition of the reading disorder, the causes and its characteristics.

One of the topics of debate on dyslexia is the definition of the term. Professor Julian Elliott, one of the authors of a recent controversial book "The Dyslexia Debate", argued that dyslexia is a "meaningless" label that is holding back teachers and parents from truly helping children with their individual reading difficulty (Elliott & Grigorenko, 2014). His arguments starts almost 10 years ago suggesting that dyslexia does not exist. Elliott (2005) believes that the term is problematic due to a wide range of difficulties experience by the dyslexic individuals. The diagnosis of dyslexia is also regarded as unscientific because the criterion researchers or people use to identify the learning disability varies between one and another. He acknowledges the existence of real difficulties that individuals have in learning how to read and how to decode text. However, problems in identifying a smaller group of children from those who have reading difficulties as being dyslexic need to be look into. Another point of argument from the author is the method of intervention. There is no specific intervention or educational treatment than is only applicable to the dyslexic child without also benefits a child with reading difficulties (Elliot, 2005; Elliot & Grigorenko, 2014).

Concerns and debates with regards to definition, diagnostic and treatment among researchers and practitioners show how dyslexia as a learning disability has constantly being investigated and revised. Many still believes that the definition and diagnosis of dyslexia is important to help understand the reader's struggle and identify the best intervention methods (Bates, 2014). A discussion relating to definition, comorbidity and subtyping of dyslexia will be presented next followed by theories related to the reading disorder.

A definition of dyslexia

There was a significant amount of evidence based on the literature that dyslexia can be defined as a combination of difficulties that affect the learning process in one or more of reading, spelling, and writing (Aaron, 1997; Stanovich, 1998, 1999; Lyon, Shaywitz, Shaywitz, 2003; Klassen, 2002; Klassen, Neufeld, & Munro, 2005; British Psychological Society, 1999; Velluntino, Fletcher, Snowling, & Scanlon, 2004). The definition of dyslexia (reading disorder) based on DSM-IV-TR (2000) which is used for diagnostic purposes, is stated as follows:

"oral reading is characterised by distortions, substitutions, or omissions; both oral and silent reading are characterised by slowness and errors in comprehension" (p. 51-52).

While, based on working memory theory, McLoughlin et al. (2002) have proposed the following definition:

'Developmental dyslexia is a genetically inherited and neurologically determined inefficiency in working memory, the information-processing system fundamental to learning and performance in conventional education and work settings. It has a particular impact on verbal and written communication as well as organization, planning and adaptation to change' (p.19).

Lastly, an updated definition of dyslexia from the British Dyslexia Association (BDA) in 2007 denotes dyslexia as a specific learning difficulty which is present from birth and persists throughout the lifespan. According to their definition, dyslexia affects the development of literacy and language skills. It can also manifest itself as difficulty with phonological awareness, phonological decoding, processing speed, auditory short-term memory, language skills or verbal comprehension, working memory and or rapid naming. The dyslexic children find themselves difficult to adapt to the main stream teaching methods, however suitable intervention specifically designed for them can help reduce these difficulties with proper use of technology assistance. In this thesis, dyslexia can be operationally defined as difficulty in learning to read, write and performing learning activities sufficiently despite having average or above average intelligence and adequate education.

Comorbidity issues & subtypes of dyslexia

An important point to consider when discussing about dyslexia is to look into the comorbidity issues and the different types of dyslexia. There is a limited study on the comorbidity of dyslexia with other disorders. One of the studies was conducted by Pauc (2005) which is a prospective study aim to examine the comorbidity incidence of a range of disorders which among others include dyslexia, attention deficit disorder (ADD), ADHD, and dyspraxia. In his findings, 38% of the dyslexic group was presented with ADHD and 62% with ADD. The findings suggest that some difficulties shown by dyslexic individual may be related with other disorders that are affecting their performance. Examples include brain abnormalities that affect various systems involving attention, processing, comprehension and storage. The different types of dyslexia can be divided into two different groups; the first is acquired dyslexia which resulted from a known type of brain damage, the second group is developmental dyslexia where the difficulty lies in the initial learning to read and write with no identifiable brain damage (Rayner & Pollatsek, 1989).

Acquired dyslexia

Acquired dyslexia or alexia is a reading disorder that usually occurs after a brain damage (example: stroke or atropy) in previously literate person. There are several forms of alexia that includes pure alexia, surface dyslexia, semantic dyslexia, phonological dyslexia and deep dyslexia (Spivey, Joanisse, & McRae, 2012).

Individuals with surface dyslexia show pronounciation errors that indicate impairment of the lexical route. According to Patterson, Coltheart, & Marshall (1985), they are able to pronounce words correctly, but have difficulty in the semantic representation of the words. They are able to pronounce regular words correctly more often than nonwords.

Developmental dyslexia

According to the International Classification of Disease (ICD-10), the developmental dyslexia is a specific and significant impairment in the ability to learn to read and perform reading activity despite having adequate education and above average intelligence (World Health Organization, 2011). Similarly, based on DSM-5 insists that

> "the learning difficulties are not better accounted for by intellectual disabilities, uncorrected visual or auditory acuity, other mental or neurological disorders, psychosocial adversity, lack of proficiency in the language of academic instruction, or inadequate educational instruction" (American Psychiatric Association, 2013)

In view of the different subtypes of dyslexia with specific underlying characteristics associated with them, extensive research has been done investigating the underlying cause of these difficulties. The following section will discuss theoretical arguments with regards to the deficits associated with dyslexia.

1.4.1 Theories of dyslexia

Drawing from the various definitions, there are also many theories on what causes dyslexia. However, Frith (1997, 1999) suggested a framework known as a "causal modelling framework" which helps to explain and understand dyslexia. The framework consist of 3 levels of description at the biological (genetics and neurology), cognitive (information processing), and behavioural levels.

Behavioural level

At the behaviour level, the biological and cognitive factors can result in difficulties in learning to read, spelling, writing (often reversing the orientation of letters or omitting letters when writing), phonic skills, speech development and others. According to Frith (1999, 2006), the observed behaviour are generally due to a mixed of underlying causes (biological and cognitive) along with environmental factors that impact the behavioural outcome.

Biological level

Investigations to the underlying causes of dyslexia have also focused on the genetic factors and physiological dysfunction of a dyslexic brain. A brief summary of the core arguments are discussed which include the investigation in the structure of the brain, magnocellular pathway theory and cerebellar deficit hypothesis.

Modern neuroscience research using technologies such as positron emission tomography (PET) and magnetic resonance imaging (MRI) have produced clear differences in the structure of the brain of a dyslexic. Brunswick and colleagues found less activation in the left posterior temporal cortex in the adult dyslexic group when performing word and non-word recognition tasks compared to the control group, suggesting that there may be some deficits in the left hemisphere processing among individuals with dyslexia (Brunswick, McCrory, Price, Frith & Frith, 1999). While using fMRI, Shaywitz (2003) found an overactive frontal part of the brain and a weak activation in the back of the brain of the dyslexic reader during reading tasks which was the opposite in good readers, suggesting differences in how the dyslexic brain functions. Therefore based on brain activation studies using neurosciences imaging tools such as PET scan, MRI and fMRI, it has been found that people with dyslexia displayed deficits in the left hemisphere of the brain that has been implicated with language/reading which includes the inferior frontal gyrus, inferior parietal lobule, and middle and ventral temporal cortex (Cao, Bitan, Chou, Burman & Booth, 2006; Shaywitz, Lyon & Shaywitz, 2006). Earlier research involving post-mortem analysis between dyslexic and control brains, found differences predominately in the left perisylvian cortex (Brown et al., 2001; Eliez et al., 2000).

The magnocellular pathway theory suggests that the literacy difficulties in dyslexic may be the result of impairment in the development of a system of large neurones in the brain called magnocells that is responsible for timing sensory and motor events (Hansen, Stein, Orde, Winter & Talcott, 2001; Stein, 2001; Stein & Talcott, 1999; Stein & Walsh, 1997). The impairment could lead to weaknesses in the magnocellular and parvocellular visual and auditory systems where visual confusion of letter order and poor visual memory for the written word could occur when visual reading, while confusion of letter sounds occurs during the phonological demands of reading is required (Stein, 2001; Stein & Walsh, 1997; Everatt, 2006).

On the other hand, the cerebellar deficit hypothesis suggests that the dysfunction in the cerebellum (the part of the brain that is thought to be responsible for dexterity and automaticity) offers an explanation for the difficulty of dyslexic children to perform any automatic skills including reading (Nicolson, Fawcett, Moss, Nicolson & Reason, 1999; Nicolson, Fawcett & Dean, 2001). Lack of automaticity in reading or numeracy could mean that dyslexic individuals are more likely to experience processing overload when they are required to perform new or complex tasks. Less 'automatic' means more concentration and attention is required from the dyslexic individuals compared to non-dyslexic individuals and responsible for weakness in articulatory and auditory skills important for the grapheme-phoneme correspondence and the control of eye movement (Fawcett, Nicolson & Dean, 1996; Fawcett & Nicolson, 1999; Fawcett & Nicolson, 2001). However, findings from Ramus, Pidgeon and Frith (2003) and Heim et al., (2008) research showed no differences on automatisation tasks in dyslexic group therefore challenging the automaticity hypothesis.

Overall, the biological theories provide strong evidence linking the behavioural signs associated with dyslexia. The differences in brain structures of dyslexia compared to the normal individuals as well as neurobiological brain abnormalities provide insight into the cognitive deficits associated with this learning disability.

Cognitive level

Phonological deficit theory

Some researcher insists that phonological processing difficulties are fundamental to dyslexia and can be found in all dyslexic individuals (Goswami, 1999; Rack, 1997; Snowling 2000; Vellutino, 1979). Individuals with dyslexia faces major problems with literacy hence places phonological processing difficulties at the heart of the disability (Snowling, 1995). The dominant phonological deficit theory attributes the child’s reading difficulties to an inability to establish the phonological pathway between phonology (sound), orthography (print), and semantic (meaning) (Seidenberg & McClelland, 1989). Therefore a phonological deficit pre-dates the consequence (e.g. a reading problem). Previous studies investigating phonological awareness in children and adults with dyslexia have shown that the dyslexic performed worse compared to RA (Reading Age)-matched controls in phonological awareness tasks thus confirming this pattern of impairments in dyslexic individuals. Phonological awareness tasks measure an individual’s ability to make explicit judgements about the sound structure of spoken words. Thus in children with dyslexia, the ability to analyse speech at the phonemic level appears to be particularly closely related to the ability to learn to read (Bruck, 1988, 1990; Manis, Custodio, & Szeszulski, 1993; Windfuhr & Snowling, 2001).

Children with dyslexia also show difficulties on phonological processing tasks such as a word or non-word repetition (repeating a word or non-word), naming a picture, or remembering a list of words. The tasks require the child to use speech, without reflecting upon the structure of spoken words. Research investigating the performance of dyslexic children in non-word task found that the children have difficulty repeating non-words compared to RA controls (Snowling, 1981; Rack, Snowling & Olson, 1992). Further research has shown that non-word repetition is a good indicator of vocabulary acquisition (Baddeley, Gathercole, & Papagno, 1998) and of foreign language learning (Service, 1992). Snowling, van Wagtendonk, & Stafford, (1988) did a research investigating naming difficulties in dyslexic children and their data indicated that dyslexic children have difficulties in confrontation naming (expressive vocabulary) with normal performance on word/picture matching task (receptive vocabulary). Naming is a memory retrieval task where visual stimulus is used as a cue to retrieve the name of an object from memory. Difficulties in naming provide evidence that this retrieval process is inefficient in children with dyslexia. The naming difficulties shown in dyslexia are consistent with the idea that semantic information (word meanings) is adequately represented in memory but that phonological information (word sound) is poorly represented (Swan & Goswami, 1997).

Working memory deficit theory

As the present thesis is concerned with the cognitive abilities or difficulties of dyslexic adults in terms of working memory, a brief summary will be presented here where a more detailed explanation has been discussed in the earlier sections of this chapter. Swanson (1994) found that short-term memory and working memory to be significant predictors of reading comprehension. It is assumed that working memory act as a workbench that holds the constituent sounds and phonological codes in the short-term storage while recognising and making sense of the word or sentences with the help from long-term memory (Gathercole & Alloway, 2008).

Several studies with regards to dyslexia have shown that working memory deficits do play an important part in the reading development of dyslexic individuals in terms of phonological segmentation, rhyming (Nicholas & Fawcett, 1995), in the retrieval process within the phonological loop, and impaired language comprehension (Helland, 2006), identified deficits in the central executive (Reiter, Tucha, & Lange, 2005; Wang & Gathercole, 2013) and impaired storage within the verbal store (Helland, 2006). Therefore, the implication of working memory performance in dyslexic learners should be further investigated especially those in higher institutions since far too little attention has been paid to these group of students.

1.5 Working memory and dyslexia in higher education

Overall, dyslexia has been estimated to occur in 10% of the general population, and 4% of students in higher education are likely to show some of the symptoms of dyslexia. In 2005/2006, approximately 3.5% of the undergraduate student population in all higher education in the UK was reported as having dyslexia based on HESA figures (www.hesa.ac.uk). The numbers might be even higher than reported since many students are not in the statistical count due to not being disclosed of their disability or even might not even been accessed for the disability. Nonetheless, the numbers has been increasing gradually over recent years and the extent of the problem of this hidden disability is now being recognised. According to the Higher Education Statistics Agency, there were 104,580 students with dyslexia in 2012-2013, compared with 74,490 in 2007-2008. That is an increase of more than

30% in the number of university students reporting having the reading disability within those couple of years. This is the concern of the authors of "The Dyslexia Debate" where the dyslexia term is so broad that it encompasses of so many things under the mild literacy problems umbrella (Elliot & Grigorenko, 2014).

There are various theoretical perspectives in diagnosing and identifying dyslexia, ranging from the behavioural and biological to cognitive premises in explaining the reading disorder (Frith, 1999, 2006; Morton & Firth, 1995) and has been explained from the previous sections. From a cognitive perspective, working memory has been implicated as one of the contributing factors that are associated with dyslexia (Baddeley, 1986; Gathercole & Baddeley, 1993; Goswami, 1999; Gathercole & Alloway, 2008; Scheepers, 2009) and will be the focus of this thesis.

Research on adult dyslexic assumed that all the primary difficulties experience by this group of people stem from a less efficient working memory (McLoughlin, Fitzgibbon, & Young, 1994; McLoughlin, Leather, & Stringer, 2002). Jefferies & Everatt (2003) did a study comparing working memory performance of dyslexic and dyspraxia adults with controls and their interesting findings showed dyslexic adults performing worst in task related to the phonological loop while the dyspraxia group performed worst in task involving the visuospatial sketch pad. Therefore, based on previous literature, dyslexic learners were predicted to have weakness in their verbal working memory with no differences in performance in visuospatial working memory compared to students with no learning difficulties (Jeffries & Everatt, 2003; McLoughlin et al., 2002; Pickering, 2006a).

Thus, the working memory problems of advanced levels of study are not diminished, but are certainly different from those of the more structured classrooms of the early and middle childhood years. Research on adult dyslexic indicated that these individuals manifest difficulties with aspects of executive functioning such as attention, planning and changing set of thinking which is important in the process of learning especially in university (Venneri, 2000 cited in McLoughlin et al., 2002). They will have difficulties with reading, non-word reading, spelling and written expression or writing speed (Hatcher, Snowling, & Griffiths, 2002; Swanson & Saez, 2003) as well as difficulties with learning-related activities such as remembering instructions, pace keeping, note taking and organizations of activities (McLoughlin et al., 2002). As a college or a university student, he/she needs to apply any new skills or learn strategies to new situations and able to organize and handle time keeping issues appropriately.

Therefore, there is little evidence to suggest that working memory problems resolve with time and are likely to persist into later childhood and adulthood (Hatcher, et al., 2002). The problems these students are facing cannot be addressed by just changing the mode of curriculum delivery as in younger children. University and college students with learning difficulties need to be able to control their learning environment and skills themselves. Students are intelligent independent learners and they need support to get them through college and university. Hence, support for students in the later stage (adolescent and adulthood) often centres on the development of strategies to help overcome the consequences of working memory difficulties. The students need to be able to understand their strength and weaknesses. The surrounding people need to adapt methods of assessment and methods of instructions in order to take account these difficulties. By being aware of an individual’s memory strength and limitations or weaknesses, it can help him/her to identify suitable and appropriate compensatory learning strategies very effectively, which is particularly important especially for students with learning difficulties. With the right support and intervention, people with learning difficulties can be successful in school and continue to do well later in life.

1.5.1 Working memory, dyslexia and science learning

The previous sections discussed the importance of working memory in learning generally for individuals with learning difficulties and specifically in dyslexic students. However, we are also interested to investigate the working memory profiles of typical adult students with no reported learning difficulties comparing between them based on the discipline or courses that they took in university. Empirical evidence from research on dyslexic adult learners indicated a low verbal working memory performance from this group compared to normal typical adult students (Jeffries & Everatt, 2003; Smith-Spark & Fisk, 2007). However, the difference in working memory profiles between the groups of student might not solely be attributed to learning problems or disabilities. Interestingly, a small amount of observed evidence has pointed out that dyslexic individuals are disproportionately represented in professions and academic disciplines related to mathematics or science (Martino & Winner, 1995). There are some researchers who have explored for possible compensatory strengths associated with dyslexia and noted high incidence of individuals with dyslexia in professions requiring spatial abilities such as engineering or architecture (Geschwind & Galaburda, 1987).

Nonetheless, when comparing and exploring the working memory performance of dyslexic and science learners who has been linked with visual spatial talents and superiority (Von Károlyi, Winner, Gray, & Sherman, 2003), there was no evidence demonstrated a clear link between visual strength with dyslexic individuals (Winner, Karolyi, & Malinsky, 2000; Winner, et al., 2001). Other study suggested that the visuospatial advantage in dyslexic may possibly be gender bias and confined only to men (Brunswick, Martin, & Marzano, 2010). While, a study done by Winner and colleagues (2000) investigating dyslexic and non-dyslexic young adults performance on a number of perceptual and spatial tasks found no significant difference between the two groups. On some tasks, the non-dyslexic participants relatively outperformed the dyslexic. Winner's explanation is based on a subtype of dyslexia that is not easily detected in a heterogeneous group that may hold special talents such as visual advantage. However, there are studies that implicated visuospatial short-term and working memory deficits in dyslexic children (Palmer, 2000; Pablano, Valadez-Tepec, de Lourdes Arias & Garcia-Pedroza, 2000; Swanson 1999). Therefore it might not be clear on the profile of visual working memory of individual dyslexic based on the conflicting literatures. One might expect to see the same working memory profile between dyslexic and science students where a visual working memory advantage is seen if visual strength is associated with dyslexic and science students. Thus, in study 2, we wanted to investigate the working memory profile of science students in university. One would predict science students to have visual spatial advantage compared to typical non science students.

1.6 Working memory and science

The involvement of working memory in scientific learning is becoming an increasingly important topic of discussion among educators. They wanted the transfer of knowledge to young learners to be successful. Science is a very complex discipline that is acquired through the study or the practice of using observation and experimentation in order to describe and explain a natural phenomenon. In the present thesis, the field/discipline of science will be confined to include only some of the natural sciences disciplines (the study of the natural world) such as physics, chemistry, biology and environments that are being offered as university degrees. Research in science education has demonstrated that much of the learner's difficulty in part of physics and chemistry as well as other areas of biology lie in the limitations of working memory capacity (St Clair-Thompson & Botton, 2009).

Researchers in science and technological education have recently explored the relationship between working memory and science attainment within the context of multi–component of working memory. St-Clair Thompson, Overton and Bugler (2012) examined the relationship between mental capacity and working memory in problem solving and attainment in chemistry. Their results revealed that performance in the working memory task (e.g., counting recall) is the best predictor of A level chemistry grades and algorithmic problem solving.

Science is very much conceptual. To understand certain concepts, students often need to hold much information about one concept while at the same time processing new information so that the next concept can be developed and this is the start of much difficulty in science. Based on Johnston model (Figure 1.4), in the early stages of teaching science (biology, chemistry, and physics), the important key point is to focus on the macro level which can be perceived directly by the senses (Johnstone, 1999). For example, students need to understand the 'macro' part of chemistry such as precipitations, colour changes, evolution of gases, coloured flames and even different explosions through observation. However, in order for student to appreciate the concept of precipitations, they need to be able to interpret sub-microscopic level such as atoms, molecules, ions, bonding and energy which is not directly observable. Students also need to be able to represent the macro and sub-microscopic levels in terms of scientific diagrams, mathematical formulae or symbols. Overloading the working memory by introducing two or three levels of the vertices at the same time will cost dearly to students by not being able to cope and understand the concept and relationship fully. Once the students are able to grasp one concept, the next area/vertices can then be introduced (Hussein & Reid, 2009).

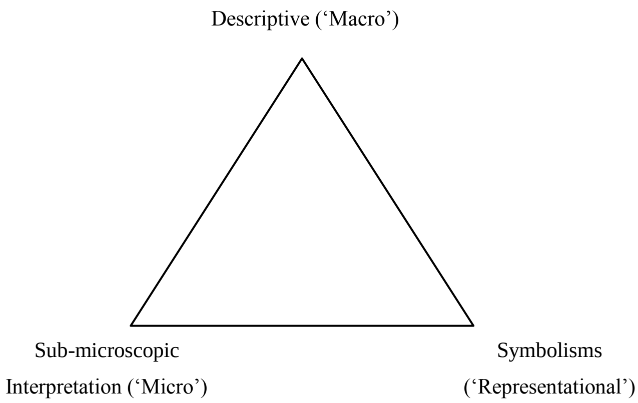


Figure 1.4 Chemistry triangle (Johnstone, 1997)

Because of the role of working memory as a thinking-holding space, educators need to find ways not to overload students working memory capacity so that learning can take place. This is because research has shown that students with higher working memory capacities were found to consistently understand the ideas of physics much better than those with lower working memory capacities (Chen & Whitehead, 2009). Their findings were consistent with previous literature on working memory and learning (Jarvis & Gathercole, 2003; Reid, 2009; St Clair-Thompson & Gathercole, 2006). Given the nature of science (study based on observation and experimentation), visual-spatial advantage might be particularly important as well to science students. There have been well documented studies that reported evidence of domain specific links between working memory and learning with the strongest associations between verbal working memory and standardised attainments in English and between visuospatial working memory and attainments in mathematics (Bull, Johnston & Roy, 1999; Holmes & Adams, 2003; Holmes, Adams & Hamilton, 2008) and science.

There is no known study investigating the working memory performance of science and humanistic learners. However, there were studies that investigate the relationship between students' working memory capacity and their performance in tests and examinations in science subjects such as chemistry, physics, biology and mathematics (Reid, 2009). Findings from these studies showed high correlations of working memory and performance. Backward digit span task and the Figural Intersection Test task were used to measure working memory capacity. Both of these tasks have been argued to come from different theories of cognitive resources (St Clair-Thompson & Botton, 2009; St Clair-Thompson, Overton & Bugler, 2012). Within the multi-component model of working memory, the backward digit span and listening recall tasks have been used to assess verbal working memory and can be differentiate between short-term memory task which only involve storage of either verbal information (digit recall) or visuospatial information (mazes memory).

However, research in science education has only been concerned with mental capacity of students and not in working memory capacity (St-Clair-Thompson & Botton, 2009; St-Clair-Thompson, Overton & Begler, 2012).). For example, in Chen and Whitehead (2009) study, they measures working memory capacity by using the Pascual-Leone's Figural Intersection Test (Pascual-Leone, 1970) which is based on the information processing and unitary model (concept of mental capacity). In this thesis, all the memory tasks will be based on the multi-component model of working memory (Baddeley, 1986) with tasks measuring both storage as well as processing components of both verbal and visuospatial domain.

A recent study conducted by Kyndt, Cascallar and Dochy (2012) on 128 university students examined the relationship between working memory capacity and attention and students approaches to learning. The university students were studying educational sciences. Their research discovered that students with high working memory capacity scored lower on both deep and surface approaches to learning than students with low working memory capacity. Their result also showed a negative relationship between attention and deep approaches to learning. They argued that the reason why high working memory capacity students might not need deep approach in learning is because these students are very good in acquiring, processing and integrating new information before sending it to storage (Kyndt et al., 2012). However, other research indicates that students with high working memory capacity used more effective learning strategies (Dunlosky & Kane, 2007; Unsworth & Spillers, 2010) that avoided dependence on route learning methods associated with surface approach. Thus there is a need to investigate whether students in different disciplines have dissimilar working memory profiles as well as diverse approaches in learning.

1.7 Other factors of success in learning: Study skills and learning styles

There are no specific factors that determine an individual’s success in learning but a convergence of factors and with support from previous literature and empirical findings we have included working memory as one of the important factors towards successful learning. Another important determinates of academic success that has been of interest to some researcher are the strategies students employed to support their learning (Yip & Chung, 2002, 2005). A meta-analysis study conducted by Crede and Kuncel (2008) suggest that study skills are important predictor of academic success and are consider equally important as academic grades or scholastic tests (Urciuoli & Bluestone, 2013). Factors such as individual study skills and learning styles can influence success in academic settings. Jeffries and Everatt (2003) interesting findings on the working memory profile of adult dyslexic encouraged us to investigate as well the learning and study skills of these individual learners. Their results implied that the working memory model may inform compensatory strategies for learning. Since based on working memory empirical findings, a general profile of adult dyslexic is displaying weakness in the phonological loop with normal or advantage in their visual sketchpad, the use of visual strategies such as mind map or external aid by using technology might be helpful to assist the learner with planning and note taking. Differences in learning styles and study skills might exist between adult learners with learning difficulties and typical normal students. Hence, in this thesis, we will also investigate factors that are commonly link with success in learning which is individual’s learning styles and study skills.

1.7.1 Learning and study skills

Study skills or study strategies are approaches applied to learning that assist students to become successful in schools in a way of passing an exam or even obtaining good grades. The key strategies include a variety of behaviours and activities, such as note-taking, organizing information, scheduling, concentrating, internal motivation, processing and mentally storing information and so on (Weinstein, 1988; Minnaert & Janssen, 1992). Effective study skills are associated with positive outcomes in multiple academic areas and for diverse learners (De Zoysa, Chandrakumara, & Rudkin, 2014).

There are a number of studies investigating the relationship between study skills and academic performance of high schools and university students. The findings from this research showed differences between high and low achieving students in terms of their learning and study strategies with attitude and motivation being the two differentiating factors (Albaili, 1997; Yip, 2007). Yip (2007, 2009, 2012) studies have investigated learning and study strategies between high and low academic achievers in Hong Kong at both secondary and tertiary levels of education. In all of his studies, participants completed a revised Chinese version of the Learning and Study Strategies Inventory (LASSI: Weistein, Zimmerman & Palmer, 1988; Weistein & Palmer, 2002). High academic achievers scored significantly higher than low achievers in all LASSI subscales. The findings implied that the better the students apply the learning and study strategies the higher their academic performance.

The Learning and Study Strategies Inventory (LASSI) model of strategic learning was developed by Weinstein, Husman, and Dierking (2000) to unravel students' academic performance. The strategic model was designed around three interconnecting core components of learning: will; self-regulation; and skill. Figure 1.5 shows LASSI scales related to the will, self-regulation, and skill component of strategic learning. The will component evaluates students' perception of self-efficacy and measures the degree to which students are able to maintain motivation and sustain positive attitude towards learning. The skill component evaluates students' cognitive and processing ability in identifying, acquiring and constructing meaning for important new information, ideas and procedures, and how the students' prepare for and demonstrate their knowledge in tests or on other evaluative forms. The self-regulation component evaluates students' ability to manage or self-regulate and control the whole learning process through the use of their time effectively, focusing their attention and concentration on work at hand and the use of self-testing strategies and other study aids available. This survey instrument provides standardised scores identifying students' strengths and weaknesses in their learning and study strategies.

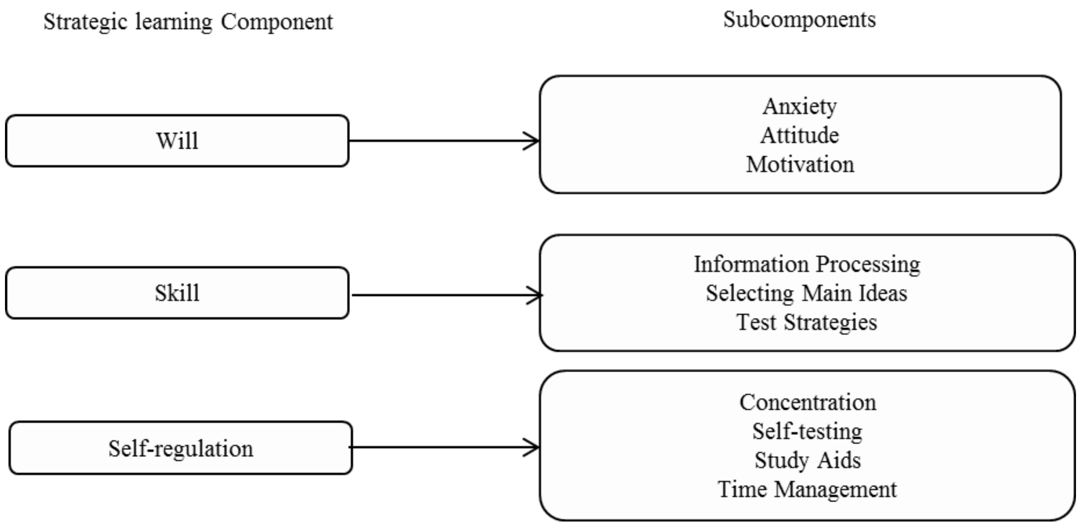


Figure 1.5 The Learning and Study Strategies Inventory (LASSI) model (Weinstein et al., 2002)

The next section will also discussed the different learning and study skills profile of student with learning difficulties such as dyslexia.

Study skills and dyslexia

Findings from questionnaire and survey studies of students with and without dyslexia in higher education found that students with dyslexia reported having problems with a wide range of academic related skills such as note taking, organization of essays and expressing of ideas in writing assignments (Mortimore & Crozier, 2006). This is consistent with previous empirical studies investigating study skills of college students with and without learning disabilities also indicated differences between these two groups. Kirby and colleagues (2008) compared self-reported learning strategies and study approaches of postsecondary (university and colleges) students with and without dyslexia as well as examining the relationship of those characteristics with their reading ability. Students with dyslexia were found to use more study aids and time management strategies while using less selecting main ideas and test taking strategies compared to students without dyslexia.

The dyslexia group also reported to apply a deep approach to learning compared to the other groups. What is most interesting is that the reading ability of the two groups of students correlated positively with selecting main ideas and test taking strategies and negatively with use of study aids. The higher the reading ability a student has, the higher their ability at identifying important information and at using test taking strategies while using less resources and support techniques to help them learn and remember new information. Thus, implying that the weakness that the dyslexic have in reading (notes and textbooks) might contribute to these students reporting using less selecting main ideas techniques and test taking strategies compared to the other group (Kirby, Silverstri, Allingham, Parrila & Fave, 2008).

Other research (Proctor, Prevatt, Petscher, & Adams, 2006; Kovach & Wilson, 1999) has also shown that adult dyslexic use learning strategies and techniques differently to partially circumvent the difficulties they experienced in learning generally and word learning specifically. Study skills profiles of typical students were compared with learning disability students. Their learning and study strategies and performance anxiety showed significant difference between the two groups. The academically struggling college students were found to displayed weakness in study skills in five areas; anxiety management, concentration, motivation, selecting main ideas, and test taking strategies. Strategies are therefore useful for students to maximize the strength that they have while reducing demands on working memory. Students can use technological aids such as time management software, spell checker, computer and audio recorder, note aids and others that the disability student support from university can provide. Both Kirby et al. (2008) and Proctor et al. (2006) conducted their research using the Learning and Study Strategies Inventory (LASSI) developed by Weinstein & Palmer (2002).

Overall, Kirby's et al. and other college disability studies showed that postsecondary students with dyslexia reported a learning strategy and study profile that is distinct from that of other students (Kirby et al., 2008; Kovach & Wilson, 1999; Proctor et al., 2006). One of the aims of this thesis is to increase understanding of the cognitive limitations and compensatory strategies of students with learning difficulties in order to provide appropriate instructions in learning strategies in order to maximize academic success. For the purpose of evaluating students' learning and study strategies, the Learning and Study Strategies Inventory (LASSI) used by these researchers was adopted. The instrument has been shown to be reliable and applicable to different levels of education (schools, college & universities) and different countries with different cultural backgrounds (Yip, 2007; 2009; 2013; De Zoysa, Chandrakumara, & Rudkin, 2014; Albaili 1997).

1.7.2 Learning styles

Learning styles on the other hand are various approaches of learning and represent “a person’s typical models of perceiving, remembering, thinking and problem solving” (Keefe, 1987; Messick, 1976) or a student’s way of “responding to and using stimuli in the context of learning” (Clark, 2004). There are a large body of research indicating that students have different learning styles (Felder, 1993). Students have different levels of motivation, attitudes and responses towards learning, thus this affects their individual’s preferences on how they learn (Feder & Brent, 2006; Wintergerst, DeCapua, & Itzen, 2001). The importance of learning styles in learners’ academic achievements has been well documented (Coffield, Moseley, Hall, & Ecclestone, 2004; Campbell & Johnstone, 2010; Komarraju, Karau, Schmeck, & Avdic, 2011; Naimie, Siraj, Piaw, Shagholi, & Abuzaid, 2010), although there are other evidence suggesting learning preferences have no influence in academic results (Pashler, McDaniel, Rohrer, & Bjork, 2010). An important thing to bear in mind is that there is no single learning style that is better or worse than the others. Often an individual will differ in terms of which type of learning methods suits them best based on their strengths and preferences in learning and by highlighting and acknowledging these differences, students as well as instructors will gain benefits from it despite the criticism (Felder, 2010).

There are many learning styles models that are commonly use today. These models of learning style have been advanced to explain the different descriptions and classification of learning styles or preferences. Kolb’s Experiential Learning Theory comprises of four-mode learning cycle that includes Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation. Kolb defines learning as the processes whereby knowledge is created through the transformation of experience (Kolb, 1984 cited in Hawk & Shah, 2007). Learners start their learning cycle by interacting with their environment creating concrete experience. Next, the learners are involved in reflective observation when the information received from the environment is integrated and compared to long term knowledge. New ideas, models and plans for action are created from the observation (abstract hypotheses and thinking) and finally executing the action (active testing). According to Kolb, the most effective mode towards learners is when learning constitutes all of the different experiences especially in the concrete (active) and abstract dimension (intellectual). The four learning cycles are associated to the four learning styles which is assimilators, accommodators, convergers, and divergers.

Other models of learning styles include the Honey and Mumford (1992) model which was an adaptation from Kolb's experiential learning model. Honey and Mumford's Learning Styles Questionnaires (LSQ) was developed for use in industry and management settings (management trainees) identifying four different types of learners which is activist, reflector, theories and pragmatist. Activists are active learners, intuitive and dislike structured procedure, reflectors on the other hand observe and describe processes and reflect on previous knowledge to inform learning. Theorists focus on basic assumptions, ideas, and step by step logical thinking while pragmatists keen to try out ideas and experiment, and are practically down to earth individuals. Although the development of LSQ specifically for use in the industry (management), it has also been used in other settings including education (Van Zwanenberg, Wilkinson & Anderson, 2000). The purpose of both Kolb's and LSQ is to inform learners about their learning preference so that they can either matched the learning activity with their preferred style or practice using or encourage to use their less preferred style.

Fleming's VARK model (Visual/Aural/Read/Kinesthetic) is another learning style inventory developed by Felming in 1987 to identify individual learning preferences (Hawk & Shah, 2007). The VARK questionnaire profile learners whether they have a preference for visual learning (drawings, pictures, maps, diagrams, movies), auditory learning (music, lectures, discussions, podcasts), reading and writing (reading notes/textbooks, taking notes) or kinaesthetic learning (hands on activities, experiments, manipulating objects). The VARK questionnaire contains between 13 to 16 questions and has been kept simple and short to avoid student survey fatigue and encourage respondents to reflect from their learning experience rather than from hypothetical situations (http://www.vark-learn.com). VARK questionnaire is commonly used due to its simplicity especially by students and school and university teachers/professors to assist them in understanding the learners better. The result from VARK can be used to provide insight into individual's learning preference as well as providing strategies for using those preferences to enhance learning (Fleming & Baume, 2006).

Although there are various learning style questionnaire and models that has been used in research, another learning style model that is commonly used especially in the science field is the Felder-Silverman Learning Style Model (FSLSM). The Felder and Silverman model focuses on information processing preference of learners. The model examines preference of students in processing, assimilating, and creating new information and knowledge through experience (Hawk & Shah, 2007). It was used to investigate the learning styles of engineering students in order to develop a teaching style that can match and enhance students' engagement during class. This learning style model was created to identify the learning preferences of an individual learner and was based on Kolb's model theory. The questionnaire focused on the characteristic strength and preferences in the way an individual take in and process information (Felder & Silverman, 1988, p.674). It classifies learners as having preferences for one category or the other in the following four dimensions: the Active-Reflective, the Sensing-Intuitive, the Verbal-Visual, and the Sequential-Global. Each individual learner will have different learning styles, thus the main purpose of knowing an individual's learning preference is to adapt and create a learning environment that is best fitted for different type of learners (Felder, 1993; Felder & Silverman, 1988; Tanner & Allen, 2004).

In this thesis, we investigate the learning style of adult students based on the Felder and Silverman Index of Learning Style questionnaires due to empirical research indicating its relationship with working memory capacity. Graf, Lin, and Kinshuk, did a comprehensive literature review on studies that investigated the relationship between the Felder-Silverman learning style model and working memory capacity. Based on the literature search, a relationship between high working memory capacity with reflective, intuitive, and sequential learning can be identified while in contrast, individuals with low working memory capacity prefer an active, sensing, and global learning style (Graf, Lin, & Kinshuk, 2008). Graf and colleagues in 2006 conducted an exploratory study with 39 students to verify the proposed relationship. Their data displayed interesting findings where significant correlations were found between working memory capacity and two of the four dimensions of the learning style model which is the sensing/intuitive and the visual/verbal dimension (Graf, Lin, & Kinshuk, 2008; Graf, Lin, Jeffrey & Kinshuk, 2006). With regards to the verbal/visual dimension, only a relationship in one direction was found. Learners with low working memory capacity tend to prefer visual learning style although; learners with a visual learning style do not necessarily have low working memory capacity. The mass use of learning style questionnaires to identify individual preference and style of learning have received critics mainly due to the various "dimensions" of learning style that are complex and not entirely understood. Knowing one's learning style does not directly improves learning. However, knowing one's learning style can be the first step in self-awareness or metacognition skills in reflecting and understanding one's own learning process, resulting in better strategies and use of their learning styles.

Learning styles and dyslexia

Student with dyslexia process information differently to the majority of other learners, it is important to investigate whether students with dyslexia have a preferred learning style and how these individuals and their support system will respond to it. For students with dyslexia or other learning disability, it is important that their learning is optimized in any learning environment.

A research conducted by Exley (2003) examined the effectiveness of teaching strategies for students with dyslexia based on their preferred learning styles. She investigated whether teaching to the preferred learning style of students with dyslexia can improve their performance and attainment in both literacy and numeracy. She uses both quantitative and qualitative methods on seven dyslexic students in her school. This includes interviews, observation, questionnaires and mathematics and spelling tests. Based on her findings, all seven students showed marked improvement in their performance once their preferred learning style has been established and used in the teaching and learning activities. Five of the students also showed improvement in their numeracy and spelling tests. The majority of the students also favoured a visuospatial/kinaesthetic learning style. Although this is a small-scale study, Exley's research contributes towards positive conclusion drawn from understanding dyslexia learning styles (Michail, 2010). Investigating study skills and learning styles of typical and atypical learners can contribute towards understanding individual differences in classroom or any learning environments. Individuals who have reached tertiary level of education (enter college or university) and have learning difficulties such as dyslexia or those who have low working memory capacity may have study strategies or skills and learning styles that successfully compensate for their deficits.

1.8 Working memory and general intelligence

In the early days of psychology, general intelligence has been associated with an individual's ability to think about ideas, analyse situations and solve problems. Intelligence quotient (IQ) represents a score of the mental ability of a person compare to another of the same age and it is measured through various types of intelligence tests. There has been substantial literature demonstrating the relationship between IQ scores and educational success (Kline, 1990).

Among the most administered IQ tests is the Wechsler tests consists of 10 to 14 subtests, half of which is verbal where the questions and answers were communicated orally. Examples of verbal subtests include Information (measures the participant's store of general information) , Similarities (measures the participant's ability to categorize), Arithmetic (measures the participant's ability to solve arithmetic problems), Vocabulary (measures the participant's range of vocabulary), Comprehension (measures the participant's ability to answer common sense questions), and Digit span (measures the participant's ability to recall a string of digits and to repeat them backward). The maximum number of digits to be recalled and repeated in reverse order is 9.

The other half subtasks in the Wechsler tests consist of nonverbal or performance subtests in which participant has to perform certain tasks as fast as possible. The nonverbal tests include Picture Completion (telling what's missing from various pictures), Coding (The participant is shown a table of digits and corresponding symbols, and is then asked to fill in digits for a "message" made up of a string of symbols, Picture Arrangement (arranging pictures so that they tell a story), Block Design (arranging multi-colored blocks to fit a set of printed designs), and Object Assembly (Putting puzzles together, as a measure of non-verbal fluid reasoning) (Wechsler, 1997). In all the studies reported in this thesis, only four subtests from the Wechsler Adult Intelligence Scale-III were chosen and used to provide an estimate of the general intelligence of the participants (Chan, Chen, & Chan, 2005). Apart from working memory performance, we are also interested to find out whether IQ will be able to discriminate between individuals with and without learning disabilities.

Although measures of general intelligence or IQ has been regarded as a strong predictor of academic learning and success in life, an IQ scores seems to fail to answer questions with regards to why some students with normal intelligence have been associated with learning difficulties such as dyslexia. It has been argued that IQ scores are not as good as working memory measures to reflect an individual’s true learning potential (Alloway, 2009). This is because, IQ tests which are often used as a school based intelligence tests, measured knowledge an individual already have in their head while working memory capabilities were found to have a link to an individual ability to learn. Few empirical studies show that working memory were found not to be effected by experience such as from prior education, socio-economic status (Engel, et al., 2008) or from ethnic group membership (Campbell, Dollaghan, Needleman, & Jonosky, 1997). Research by Alloway investigating the predictive power of working memory and IQ in academic performance found that working memory is a more powerful predictor of subsequent academic success than IQ (Alloway, 2009; Alloway & Alloway, 2010).

1.9 Working memory intervention

Can weaknesses in working memory be improved through training by increasing the working memory capacity? In the earlier sections of this chapter, many claims have been made on the importance of working memory in a wide range of cognitive skills especially in learning (Alloway & Gathercole, 2008; Cohen & Conway, 2008). Research based on the developmental studies on working memory and individual differences indicated that working memory impairment has an impact on learning and that the deficit persists into adulthood. These studies suggested links between working memory capacity and scholastic achievements as well as potential explanation for a variety of developmental cognitive disorders (Gathercole, Brown & Pickering, 2003; Jarvis & Gathercole, 2003; Gathercole & Alloway, 2008; Alloway & Alloway, 2009). In line with these theoretical views, an increase in the working memory capacity might be expected to result in ameliorating the learning difficulties seen in these various groups of children and adults.

Nonetheless, some psychologists believe that our working memory capacity is genetically fixed (innate) and that it is uncertain that anyone can actually increase this capacity (Miller, 1956; Cowan, 2005). Therefore, according to this view, instead of focusing to increase individual's working memory capacity, working memory interventions should focus on the effective use of existing capacity by teaching individuals cognitive strategies designed to improve performance, such as mnemonics, mind mappings or study skills discussed in the previous sections.

Recently, however, there has been several empirical studies suggesting that working memory capacity can be trained and in certain cases resulted in positive improvement in the cognitive ability and academic skills in typical and atypical children and adults (Foy & Mann, 2014; Alloway, Bibile, & Lau, 2013; Alloway, 2012; Holmes, Gathercole, Place, Dunning, Hilton, & Elliott, 2010; Klingberg, Fernell, Olesen, Johnson, Gustafsson, Dahlstrom, et al., 2005), including the elderly (Craik et al, 2007), typically developing children with low working memory capacity (Holmes, Gathercole, & Dunning, 2009) and working memory in adolescents with mild intellectual disability (Van der Molen, Van Luit, Van der Molen, Klugkist, & Jongmans, 2010).

There are several computer-based working memory training programs that have been developed and became popular because of several reasons. One of the reasons is a computer-based training can be conducted anywhere and anytime compared to a face-to-face and one-to-one intervention which can be time consuming (Wanzek, Vaughn, Wexler, Swanson, Edmonds & Kim, 2006). Secondly, the computer-based training programs contain game-like features and reward mechanism that attract and engage children and adults while applying adaptive technology to stretch and maximise the user capability. Several strong claims have been made to the effectiveness of these training programs.

One of the clinical intervention studies conducted by researches such as Klingberg, Holmes and Dunning used a well-known working memory training program called RoboMemo from CogMed (CogMed RM) and it is widely used in schools and clinics (http://www.cogmed.com). This program focused on attentional problems caused by poor working memory and was based on research on cognitive neuroscience. It consists of eight different exercises involving both verbal and visuospatial working memory tasks, where the difficulty level is adjusted according to the user capability during training. The program also has a reward element in the training where participant can play a racing game after each day of training. For example, research using RoboMemo, a computerised and systematic training on individuals who were diagnosed as having working memory deficit such as children with ADHD, were shown to have positive effects where the participants' working memory performance significantly improved as well as displaying reduced symptoms of and associated behavioural problems in ADHD (Holmes, Gathercole, & Dunning, 2009; Holmes et al., 2009; Klingberg et al., 2005). Holmes and colleagues (2009) have shown that working memory training can alleviate working memory deficits in children with ADHD in all components of working memory across untrained tasks indicating a far-transfer effect (effects on tasks quite different from those trained). The researchers also found that IQ scores were unaffected by this intervention. Another research using CogMed JM on beginning readers (5-6 years old children) also provide evidence of the effectives of the program where both near-transfer (untrained visuospatial test) and far transfer effects (tests of verbal working memory and behavioural self-regulation) were found (Foy & Mann, 2014). However, the training has no direct effects on pre-reading skills which argued the researcher might be due to limited training time (3 months). Several literatures on working memory training suggested that to find effects of training on academic skills may take more than 3 months training in order for the effects to become apparent, if there are such effects (Holmes et al., 2009; Foy & Mann, 2014).

Another computerised training program that also provides strong claims of effectiveness of training on children's learning is Jungle Memory (http://www.junglememory.com). The program requires the user to play all 3 different games that aims to exercise the verbal and visuospatial working memory. Jungle memory also motivates the user by providing rewards at the end of the exercises. The training program involves adaptive tasks that are automatically adjusted so that participants can perform the memory exercises above their current capacity. With reference to its website, Jungle memory has claimed to benefit those with ADHD, Dyslexia, Autistic Spectrum Disorders and other learning difficulties. Clinical trials were conducted with the Dyslexia Scotland and shown that dyslexic children who used Jungle Memory had improved performance in IQ, working memory and language tests. Alloway, Bibile and Lau (2013) examined the effects of computerised working memory training on students with reading difficulties and language impairments. Findings from their study indicated gains in both verbal and visuospatial working memory tasks for the high frequency training group (those who were trained four times a week) as well as improvement in spelling and tests on verbal and nonverbal ability tests compared to those in the low frequency training group (once a week training). Maintenance effects were also shown in this study after the participants were tested again at an 8-month follow up showing the same improved performance. The authors argued that the gains were possible due to the nature of the working memory exercises that involves having participants to engage in multiple executive processes in working memory tasks (monitoring and manipulating two tasks simultaneously), inhibiting irrelevant stimuli, as well as updating items for recall.

Although the above evidence shows how working memory training can improved working memory capacity and learning performance,

1.10 Overview of thesis

In summary, working memory has been widely established to be a reliable predictor of academic success in children during the early and middle school years. Poor working memory is a high risk factor for failures to achieve expected ability levels in reading and mathematics in particular. However, a lot of the research focused on children in the early stage of learning. Limited number of research investigated postsecondary students' working memory performance and study skills especially those with learning disabilities.

The purpose of this research is to investigate the role played by working memory in adult learners with dyslexia. When this research started in 2009, there was very little known about the working memory profile of students with dyslexia in higher education. Its aim was therefore to identify the working memory profiles of adult students in college and university based on Baddeley & Hitch (1974) working memory model. Whether the weakness of dyslexic individuals in the phonological storage or verbal working memory that were found in primary school children still persist into adulthood.

A further aim was to investigate the learning style and study skills that dyslexic students adopted in college and university and whether they differ from those of typical students. Being a student in college or university in a totally new environment will be stressful and hard especially for individuals with learning difficulties. Personal independence away from family and friends, students with dyslexia have to be able to cope with course workload, deadlines of assignments, meeting of appointments and managing anxiety on their own. Findings from previous research have suggested a difference in the study skills of low and high achieving students (Albaili, 1997; Kovach & Wilson, 1999; Proctor et al., 2006; Yip, 2006). In this thesis, the relationship between working memory components with other cognitive abilities (IQ) and learning skills will also be examined. For postsecondary institutions, it is increasingly important to further understand the cognitive limitations and compensatory strategies of students with learning disabilities in order to provide appropriate instruction in learning strategies and study approaches to maximize their academic success.

Next, the working memory profile, learning styles and study skills of typical adult students will also be analysed however comparing them in terms of discipline between science and humanities students. An interesting observation while conducting the first study is that the dyslexic students that participated were mostly science students majoring in biology, physics or environmental sciences. What is the working memory profile of science students? Are their learning style and study skills different from the humanities students? If there is a similar working memory profile between the science students from the second study and the dyslexic students from the first study, i.e. lower performance in verbal working memory, what does it inform about working memory in dyslexic students and typical students overall? If there is a difference in the working memory performance between science and humanities students, was it because of the working memory difference per se or a domain specific advantage? Throughout the thesis, Study 1 and Study 2 were conducted to find answers to the above questions. Assessment of working memory and cognitive skills were done via a valid and reliable instrument such as the Automated Working Memory Assessment (AWMA) and Weschler Adult Intelligence Scale (WAIS), while self-reported questionnaires were chosen to collect participants learning styles and study skills habits or preferences.

Finally, the data from the final study was analysed to explore, determine or confirm the proposed model of working memory based on the structure of verbal and visuospatial short-term and working memory in young adult learners. Structural Equation Modelling (SEM) is a confirmatory technique that was used to analyse hypothesised working memory models against observed data. Although the data is limited to fully capture the power of SEM, it is enough to test the goodness of fit between the data that we have gathered and the working memory theory.

1.11 Outline of thesis

The series of studies that form the basis of this thesis were therefore designed to provide a systematic exploration into the working memory profiles, study skills and learning styles of dyslexic and non-dyslexic adult learners. Chapter 1 starts with a literature review of working memory, dyslexia and the relationship between working memory and learning in individuals with disabilities specifically dyslexia. Other factors of learning such as learning styles and study strategies or skills are also examined. The following chapters provide detailed explanation of each study conducted in this thesis. Chapter 2 discusses Study 1 that was designed to investigate the working memory strength and weaknesses of college and undergraduate students with dyslexia, their learning styles and study skills compared to their peers (students who self-identify as having no learning disabilities) by measuring their performance in working memory and other cognitive tasks as well as by answering study skills and learning styles questionnaires. This chapter also describes the design, result and discussion of the dyslexic study. Chapter 3 introduces Study 2 that was conducted to answer question whether there is any difference in the working memory performance of science and humanistic students as well as in their study strategies using the same methodology and assessment as in the first study. Result of the data and discussion will also be presented with respect to working memory and non-dyslexic learners. Next, Chapter 4 describes and explains the use of latent variable modelling such as structural equation modelling (SEM) to examine the multiple-component model of working memory. Finally, Chapter 5 summarises the two studies and discusses the implications of the findings and future research.

CHAPTER TWO

WORKING MEMORY AND DYSLEXIA

2.1 Introduction

This chapter reports the first of two studies investigating working memory performance, study skills and learning styles of atypical adult learners. The chapter describes how these studies were conducted and explains the research design behind the study. Study 1A investigated the working memory strength and weaknesses of college students with dyslexia, their learning styles and study skills compared to their peers (students who self-identify as having no learning disabilities) by measuring their performance in working memory and other cognitive tasks as well as by answering study skills and learning styles questionnaires. Study 1B is an extension of study 1A with the recruitment of dyslexic students from the university population. University students with and without dyslexia were administered using the same materials and assessments as in study 1A to assess their working memory and other cognitive performances and study skills and learning preferences. The only difference between these two studies is that the latter study involved older students with higher educational attributes (participants were from one of the top university in the UK with high entry level requirements). The last section is the summary for this chapter.

2.2 Aim and Hypotheses

This study was set out to examine the working memory and other cognitive performance of dyslexic students in higher education institutions. Their study skills and learning preferences will also be explored. Specifically, the purpose of the present study was to investigate differences in working memory performance between adult students with dyslexia and a comparison group without dyslexia.

Below are specific hypotheses generated to investigate the relationship between working memory, study skills, learning preferences and dyslexia:

1. Dyslexic group will show significant differences in their verbal short-term and verbal working memory performance when compared to non-dyslexic group.

2. There will be no significant differences between dyslexic and non-dyslexic group in their visuospatial short-term and visuospatial working memory performance.

3. There will be no significant difference between dyslexic and non-dyslexic group in general cognitive ability tasks (Wechsler Adult Intelligence tests)

4. Dyslexic group will show significant differences in their reported study skills when compared to non-dyslexic group.

5. There will be significant differences between dyslexic and non-dyslexic group in their learning style preferences.

6. There is a relationship between working memory and study skills in adult students in higher education.

2.3 Research Design

As discussed in chapter 1, there has been a plethora of studies indicating that children with dyslexia perform poorly in tasks involving the phonological loop and in verbally-based tasks that tap the central executive (Pickering, 2006). Most of the research in this field has focused on children with few studies investigating working memory performance of the older dyslexic students who are able to continue in pursuing their education to the higher levels. This population and their educational needs are important for a number of reasons. In the recent years, there has been an increase in the number of students with dyslexia entering colleges and universities. With higher cognitive demands expected in tertiary education such strong support for students with learning disabilities has to be provided by the institutions to cater for these student’s needs. The following two studies (Study 1A and Study 1B) will hopefully add support to existing adult dyslexic studies as well as providing new knowledge in the relationship between working memory and study skills.

Due to the fact that there was no manipulation of the independent variable, the study utilised a non-experimental quantitative research (Cook & Cook, 2008; Johnson, 2001). A non-experimental research is an important and appropriate mode of research especially in the field of education since not all social scientific and educational problems are suitable for experimental manipulation (Allyn & Bacon, 1996 cited in Johnson, 2001). According to Johnson (2001), there are many independent variables that we cannot manipulate for one reason or another (unethical or impossible to manipulate) and in the present study; the independent variable was dyslexia (dyslexia/non-dyslexic) and the dependent variables were working memory performance, cognitive performance, study skills and learning preferences. Working memory and cognitive ability as well as learning strategies were assessed and compared between two groups. No random assignment was employed since the existing variable was used to define the groups.

2.4 Study 1A

Study 1A involved college students with and without dyslexia in the surrounding area of York and Leeds in the United Kingdom. Working memory was examined using the Automated Working Memory Assessment (AWMA). A total of 8 memory tasks were chosen in AWMA where each 2 tasks tapping either on the verbal short term memory, verbal working memory, visuospatial short term memory and visuospatial working memory. Participants also completed 4 subtests from the Wechsler Adult Intelligence Scale (WAIS –III) for general cognitive abilities. After that they have to answer 2 questionnaires related to their study skills and learning preferences. Chamorro-Premuzic & Arteche (2008) suggested that combining cognitive ability measures (working memory and general intelligence) with non-ability measures (such as self-reported questionnaires) will provide a broader picture of the development of students and adults in the academic settings (Kyndt, Cascallar, & Dochy, 2012). Further descriptions of the selection of participants and detail of each instrument will be explained in the following sections.

2.3.1 Method

Participants

A total of 26 college students from colleges surrounding Leeds and York volunteered to take part in this study. These students were contacted through their respective college student support advisors who were briefed about the study and willing to get in touch with the selected students. Therefore, the sampling of participants was a non-probability, convenience and purposive sampling. The support advisors identified 12 students (6 men and 6 women) as having learning difficulties such as reading and writing problems and slow in learning. Only one dyslexic student provided a Psychological Assessment Report while the other in the dyslexic group was recommended by the support advisor based on their academic and behavioural evaluation. These students comprised the Dyslexic group and ranged in age from 16 years to 22 years old, and had a mean age of 18.4 years. The remaining 14 students (10 men and 4 women) who volunteered to participate and reported no history of learning difficulties were put into the comparison group (non-dyslexic group). These students were attending the same colleges as the dyslexic group and ranged in age from 16 years to 20 years old, and had a mean age of 17.1 years. Participants were matched as far as possible on age. Consent was obtained from each student before any further information is taken. Most of the participants (85%) were from the Leeds city college through Thomas Danby, Technology Campus and South Leeds Center while the rest were from York College.

2.3.2 Task materials/ Research instruments

All of the participants completed the following assessments:

Automated Working Memory Assessment (AWMA) (Alloway, 2007)

The AWMA consists of 6 verbal and 6 visuospatial memory tasks, and is standardised for use with individuals aged between 4 and 22 years (Alloway, 2007). Participants completed 4 verbal tasks which constitute of 2 verbal short-term memory (STM) tasks (digit recall and nonword recall) and 2 verbal working memory (WM) tasks (listening recall and backwards digit recall) and 4 visuospatial memory tasks which constitute of 2 visuospatial STM (dot matrix, mazes memory) and 2 visuospatial WM (odd one out, spatial recall) were used.

These subtests in the AWMA correspond to Baddeley and Hitch (1974) working memory model as illustrated in Chapter 1. The selection of tasks were also based on research establishing them as providing valid and reliable measures of verbal and visuospatial short-term memory and working memory (refer to Chapter 1, Section 1.2). The validity and reliability of the AWMA has been verified and used in a large-scale study conducted by Alloway and colleagues in 2008. They investigated the stability and validity of AWMA by screening a large number of younger and older groups of children (Alloway, Gathercole, Kirkwood & Elliot, 2008).

Backwards digit recall and listening recall from the AWMA were administered as initial screening to all the participants. In the next two different time frames , children who obtained scores at or lower than the 10^{th} centile as those within their age group were administered the remaining 10 AMWA subtests and after an average of nine months were retested on one measures of each working memory component and compare with performance on the WISC-IV Working Memory Index. Their findings showed that working memory skills of children with poor working memory remain stable across the time frame and a high degree of convergence was found between working memory and WISC_IV performances between low and average working memory children indicating AWMA as reliable and valid instrument. The subtests selected from AWMA will be explained as follows:

Verbal short-term memory

Two measures of verbal short-term memory, the digit recall and non-words recall tests were administered in this study. In the digit recall task, sequences of digits are presented in a spoken format and the participant is required to recall each list immediately, in the correct order. Digit lists are randomly constructed from the digits ranging from 1 to 9, spoken at the rate of one digit per second. In the non-word recall task, sequences of non-words are presented in a spoken format at the rate of one syllable per second. The non-words are monosyllabic words with a consonant-vowel-consonant structure. Participant is then required to recall each list immediately, in the correct order with full accuracy.

Verbal working memory

Listening recall and backwards digit recall were subtests selected to measure verbal working memory. In the listening recall task, a series of spoken sentences are presented for which the participant is required to verify the sentence by stating “true” or “false” and recall the final word of each sentences in sequence. Test trials begin with one sentence and continue with additional sentences in each block until the participant is unable to recall three correct trials at a block. As for backward digit recall task, the same presentation of digits as digit recall tasks but the participant is required to recall the digits in a reverse order. Test trials begin with two numbers and increase by one number in each block until the participant is unable to recall four correct trials at a particular block.

Visuospatial short-term memory

In the visuospatial short-term memory tasks, the materials used include the maze patterns (mazes memory) and dot on a 4 x 4 grid (dot matrix). In the dot matrix task, a sequence of red dots is presented on a 4 x 4 grid where the participant needs to point to the positions of each dot that had appeared in the sequence in the same order. Each dot appears for 2 seconds. While for the mazes memory task, the participant is required to recall a path drawn through a two-dimensional line maze which is shown to the participant. The participant is asked to recall the path by pointing (drawing) in the same maze (now without the path) on the computer screen. Each maze is presented for 3 seconds and the maze complexity is increased by adding additional walls to the maze.

Visuospatial working memory

Visuospatial working memory is assessed using tasks such as the odd one out and spatial recall which involves storage and processing activity. In the odd one out task, the participant is presented with a horizontal row of three boxes in which three complex shapes are presented. The participant is required to point to the shape that does not match the other shapes and need to remember its location. At the end of the trial, a blank set of three boxes appears on the screen. The participant points to the boxes in which the odd shapes had appeared in the correct sequence. In the spatial span task, a picture of two identical shapes was shown to the participant. However, the shape on the right has a red dot on it and the participant identifies whether the shape on the right is the same or opposite of the shape on the left. The shape on the right may also be rotated. At the end of each trial, the participant has to recall the location of each dot on the shape in the correct order, by pointing to a picture with three compass points. Both the shapes and the compass points stayed on the computer screen until a response is given.

Procedure for administrating and scoring of AWMA tasks

A laptop computer with a screen resolution set at 800 x 600 pixels was used to present all tests of the AWMA. Instructions were automated and each subtest will begin with a series of practice trials followed immediately by the actual test. Scoring of the AWMA was fully automated and the testing sequence pre-set. The participants' responses were recorded using the left and right arrow keys on the keyboard. The right arrow key (→) recorded a correct response and the left arrow key (←) an incorrect response; the scores were automatically recorded and calculated by the program. Administration of AWMA took approximately 60 to 80 minutes. There are 6 trials in each test blocks. Participant is to complete each subtests as instructed. If a participant responds correctly to the first 4 trials within the test block, he/she is moved to another block of trials with an increased in difficulty (for example increase in the number sequence, additional sentences or larger mazes). If 3 or more errors are made, the tasks will stop. The score for each subtest will reflect the number of correct responses up to the point at which the task ended. Based on the age of the participant, his/her score on each subtask will reflect how he/she performed compared to others in the same age band which is the standardised scores. Average performance is indicated by a standard score of 100 with a standard deviation of 15. Participants who scored 85 and below (at or below the 10^{th} centile compared to those tested in their age group) will be identified as having working memory deficits.

Wechsler Adult Intelligence Scale (3rd ed.; WAIS-III; Wechsler, 1997)

The short form of WAIS-III test was administered, consisting of 4 different subtests. These subtests include Digit Symbol-Coding, Block Design, Arithmetic and Information (Blyler, Gold, Iannone, & Buchanan, 2000). The short form of WAIS-III was selected to quickly measure participant general cognitive abilities in verbal and non-verbal tasks. It is interesting to examine whether working memory performance or other cognitive abilities is better at discriminating or predicting group differences in learning difficulties.

Scaled scores are provided for each subtest and standardised with a mean of 10 and a standard deviation of three. WAIS-III also provided scores for Verbal IQ, Performance IQ, and Full Scale IQ, along with four secondary indices which include Verbal Comprehension, Working Memory, Perceptual Organisation, and Processing Speed.

Description of subtests

Digit symbol coding subtest contributes towards processing speed indices which assesses skills on focusing attention and scanning. Participant is required to code and copy some symbols within a time limit of 120 seconds.

Block design subtest contributes towards perceptual organisation indices which assesses spatial perception, visual abstract processing and problem solving. Participant is required to construct or replicate a block design from 4 to 9 blocks of cubes with all red, all white and half red and half white sides from a block design picture. Arithmetic subtest contributes towards working memory indices which assesses participant ability to hold and manipulate new information simultaneously to produce some result or reasoning processes. This subtest contains 20 arithmetic word problems where the participant is required to solve orally without the use of pencil or paper within a given time limit. Information subtest contributes towards verbal comprehension indices that measure general verbal skills such as verbal fluency and verbal knowledge. Participant responds orally to a series of questions about factual information and assesses participant's general knowledge about common people, objects, events and places.

Learning and Study Skills Inventory (LASSI) (Weinstein, Palmer, & Shulte, 2002)

LASSI-2 (Weinstein et al., 2002) is a pencil and paper 10-scale, 80 item self-report assessment of student awareness and use of learning strategies. It was administered to participants as a way to measure their use of learning and study strategies which include Attitude, Motivation, Time Management, Information Processing, Test Taking Strategies, Anxiety Management, Concentration, ability to Select Main Ideas, use of Study Aids, and implementing Self-Testing strategies. The questionnaire can be used to identify students studying strength and weaknesses that can be improved through academic and educational interventions as well as useful to learning support programs or centers. LASSI-2 was chosen as one of the instrument to measure participants learning and study skills and have been administered in various researches linking study skills with academic performance in typical college and university students (Albaili, 1997; Yip, 2007; Yip & Chung, 2002, 2005), as well as those with learning difficulties such as dyslexia (Kirby et al., 2008; Kovach & Wilgosh, 1999; Proctor et al., 2006).

A description of each item is listed below in Table 2.1.

Table 2.1 Description of LASSI subscales

Subscale	Description	Sample questions
Motivation	Motivation, self-discipline and willingness to work hard	When work is difficult I either give up or study only the easy parts. I set goals for the grades I want in my classes.
Attitude	Attitude for succeeding in school	I do not care about getting a general education; I just want to get a good job. I only study the subjects I like.
Anxiety	Anxiety and worry about school performance	When I am studying, worrying about doing poorly in a course

		interferes with my concentration. I feel very panicky when I take an important test.
Concentration	Concentration and attention to academic tasks	My mind wanders a lot when I study. If I get distracted during class, I am able to refocus my attention.
Time Management	Use of time management principles for academic tasks	I find it hard to stick to a study schedule. I set aside more time to study the subjects that are difficult for me.
Self-Testing (reviewing)	Self-testing, reviewing and preparing for classes or exams	I stop periodically while reading and mentally go over or review what was said. To check my understanding, I make up possible test questions and try to answer them.
Study Aids	Use of support techniques and materials (study groups, tutor, text book/online test)	I try to find a study partner or study group for each of my classes. My underlining is helpful when I review text material.
Information processing	Information processing, acquiring knowledge and reasoning	To help me remember new principles we are learning in class, I practice applying them. I try to find relationships between what I am learning and what I already know.
Selecting Main Ideas	Selecting main ideas and recognizing important information	I have difficulty identifying the important points in my reading. When studying, I seem to get lost in the details and miss the important information.

Test Taking Strategies	Test strategies and preparing for tests/exams	I have difficulty adapting my studying to different types of courses. I review my answers on essay tests to make sure I have made and supported my main points.

Participants responded to each item by choosing between 1-5 point Likert-type scales ranging from *not at all typical of me* to *very much typical of me*. Participants were cautioned to respond according to how well the statements reflect their behaviours or thinking processes and not how they think they should respond or how others would respond. The LASSI yields ten individual scaled scores, one for each of the ten scales. The sum of the rating scores of items in the scale yields a scale score and was compared to percentile score equivalents for each subscale.

Index of Learning Style (ILS) (Felder & Silverman, 1988)

The Felder-Silverman Learning Styles questionnaire is a 44 items test of the learning style preferences of students on 4 dimensions (active/reflective, sensing/intuitive, visual/verbal, sequential/global) and it is not considered to be a diagnostic tool. All questions are related to student preference in learning thus each participant is required to answer either “a” or “b” in different learning scenario which will then reflect their learning styles. This questionnaire has been administered to students from the engineering discipline to other students from different fields (Van Zwanenberg, Wilkinson, & Anderson, 2000). Participants required less than 10 minutes completing the questionnaire. With the focus of the thesis on students’ study skills (LASSI), ILS is another questionnaire that can identify students’ learning styles that matches their learning strengths (Zywno, 2003).

2.3.3 Procedure

The testing took place in a quiet room where participants were provided with a brief description of the study in a single session lasting approximately 90 minutes.

The tests were administered in a fixed order, with regular breaks to reduce the effects of fatigue. The AWMA was presented first followed by WAIS-III. The questionnaires were then administered last. Following the completion of the testing session, participants were debriefed, and questions with regards to the study were addressed. Participants received payment for their participation in the study.

2.3.4 Ethical Issues

The Departmental Ethics Committee, Department of Psychology from the University of York approved the research proposal (Appendix 3). The participants of the study were recruited and assessed based on the outline and description given in the proposal. Information sheet, consent forms and appropriate de-briefing were given to the participants. These are available in Appendix 1 and Appendix 2. In these documents, the participants were informed about the purpose of the study and procedures of the assessment. They were also assured about the right to refuse or withdrawn from the study at any time without penalty. Ensuring the confidentiality of participants' data during the process of data collection, data analysis and reporting of results were also explained and implemented.

2.3.5 Results

The following section will described the results of the analyses of Study1A. Inferential and descriptive statistical techniques were performed on all variables of the data to address the research questions and hypotheses of the study using SPSS version 17. Multivariate analysis of variance (MANOVA) was calculated to determine if there were significant differences between the dyslexic and non-dyslexic groups in terms of their working memory performance, general cognitive tasks, study skills and learning preferences. A MANOVA is a statistical technique for comparing multivariate means of several groups and appropriate when there are two or more dependent variables. It helps to answer if the changes or differences in the independent variable(s) have significant effects on the dependent variables (Field, 2005). Lastly, correlation analysis was performed to examine the relationship between working memory and study skills for both groups.

Assumptions of MANOVA

Before MANOVA was performed, a few assumptions need to be met in order for the result of MANOVA not to be compromised (Field, 2005; Howell, 2002). Normality distribution of data was observed and homogeneity of variance was tested using Levene's test for equality of variance and Box's test. The Levene's test showed non-significant for all the dependent variables establishing equality of variance at $p > 0.05$. Although the number of participants was unequal in each group, the ratio between the numbers of students in the two groups is 1: 1.2. MANOVA is robust to violations of multivariate normality and to violations of homogeneity of variance-covariance matrices if groups are of nearly equal size (*N* of the largest group is no more than 1.5 times the *N* of the smallest group) (Leech, Barrett, & Morgan, 2005).

Working memory

A one-way MANOVA was conducted on the AWMA data to compare the two groups on the four memory measures. The analyses were performed on the verbal short-term memory, verbal working memory, visuospatial short-term memory and visuospatial working memory composite scores. A significant group difference was found in AWMA scores with Wilks' Lambda, F (4, 21) =3.736, p<0.05, partial η^2= 0.42. A follow-up univariate analyses indicated 3 significant differences between the groups: in verbal short term memory $F(1,24) = 6.641$, p<0.01 partial η^2=0.31; verbal working memory $F(1,24) = 13.169$, p<0.01 partial η^2=0.35 and visual-spatial short term memory $F(1,24) = 4.894$, p<0.05, partial η^2=0.17. Students in the dyslexic group scored lower in all of the 3 components of memory tasks. Table 2.2 provides the measures of central tendency and other descriptive statistics for the AMWA subtests composite scores.

Table 2.2 Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 1A)

	Non Dyslexic		Dyslexic		
Measure	*M*	*SD*	*M*	*SD*	*F*
AWMA					
Digit recall	92.57	9.18	81.08	8.35	10.990**
Non word recall	93.21	9.68	86.66	15.56	1.718
Verbal STM	92.89	7.82	83.87	10.03	6.641**
Listening recall	95.43	10.53	85.00	9.42	6.977**
Backwards digit recall	96.18	9.30	82.67	8.31	15.018**
Verbal WM	95.80	8.58	83.83	8.14	13.169**
Dot matrix	93.21	13.06	86.00	15.64	1.645
Mazes memory	100.21	12.13	90.00	13.14	4.244*
Visuospatial STM	96.71	11.05	86.46	12.60	4.894*
Odd one out	99.54	26.50	87.83	12.70	1.950
Spatial recall	96.14	7.27	91.00	12.53	1.699
Visuospatial WM	97.84	13.48	89.95	11.85	2.817

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.*p<0.05, **p<0.01

General cognitive abilities (Wechsler Adult Intelligence Scale)

The data on the four cognitive tasks from WAIS-III were analysed using the MANOVA to examine whether there is also differences between dyslexic and non-dyslexic group in performing other cognitive and general intelligence tasks. Table 2.3 shows that the cognitive tasks scores demonstrated that there was no significant overall group difference between dyslexic and non-dyslexic students in WAIS-III $F(4,21) = 0.782$, *ns* ($p=0.550$; partial $\eta^2 = 0.13$).

Table 2.3 Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 1A)

	Non Dyslexic		Dyslexic		
Measure	Mean	SD	Mean	SD	*F*
WAIS-III					
Processing speed (Digit-symbol coding)	8.71	2.27	7.08	3.26	2.245
Perceptual Organisation (Block design)	10.43	2.50	10.00	2.41	0.196
Working memory (Mental arithmetic)	7.78	2.12	7.92	2.97	0.017
Verbal comprehension (Information)	7.86	2.35	8.00	3.33	0.016

Note: *p<0.05, **p<0.01

Learning and study skills performance

In order to examine whether the students with and without dyslexia differed on their learning strategies and study skills, scores on each LASSI subscales were analysed using MANOVA. For LASSI, an overall group difference was found where the Wilks' Lambda was significant, $F(10, 15) = 3.049$, $p<0.05$, partial $\eta^2=0.67$. With reference to the univariate analyses, the data indicated only one significant difference between groups where students with dyslexia were reporting lower scores on anxiety, $F(1,26) = 25.567$, $p<0.01$ partial $\eta^2=0.52$ compared to the non-dyslexic group. Students who obtained lower scores on the anxiety scale indicated a higher level of negative thoughts and cognitive worry about their academic performance. Table 2.4 provides the descriptive statistics for measures of learning and study skills.

Table 2.4 Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by Disability Status (Study 1A)

	Non Dyslexic		Dyslexic		
Measure	*M*	*SD*	*M*	*SD*	*F*
LASSI					
Anxiety	26.00	5.41	16.83	3.43	25.567**
Attitude	26.93	5.68	25.83	7.77	0.172
Concentration	20.71	5.21	18.92	4.54	0.864
Information Processing	24.14	5.40	26.50	5.71	1.166
Motivation	25.50	6.27	24.83	5.20	0.085
Self-Testing	19.00	6.24	20.00	6.67	0.156
Selecting Main Ideas	25.07	5.41	22.58	5.50	1.345
Study Aids	24.64	3.59	24.75	2.70	0.007
Time Management	19.93	4.80	18.75	2.96	0.545
Test Taking	24.57	4.68	22.50	4.27	1.260

Note: LASSI = Learning and Study Skills Inventory (Weinstein et. al, 2002); STM = short-term memory; WM = working memory. *$p<0.05$, **$p<0.01$

Learning preferences/tendency

The data measured from the Index of Learning Styles questionnaires were analysed using the MANOVA to examine whether there is also differences between groups in terms of their learning preferences or tendencies. From the data, there was no significant overall group difference between dyslexic and non-dyslexic students in learning preferences scores $F(4,21) = 1.469$, *ns* ($p=0.247$; partial $\eta^2 = 0.22$). Nonetheless, a look at the mean in active reflective learning preferences and visual verbal learning preferences shown in Table 2.5 indicates that fairly large difference exists between means and something noteworthy is going on. Individual analyses showed one significant difference in active reflective learning preferences, $F(1,24) = 5.004$, $p<0.01$ partial $\eta^2=0.17$ where students with no learning disabilities lean more towards the active learning preference while dyslexic students showed a balance in between the two learning styles.

Table 2.5 Descriptive Statistics for Learning preference (ILS) as a Function of Group (Study 1A)

Measure	Non Dyslexic Mean	Non Dyslexic SD	Dyslexic Mean	Dyslexic SD	*F*
ILS					
Active/Reflective	4.00	3.01	0.33	5.21	5.004*
Sensing/Intuitive	0.14	3.82	0.00	4.47	0.008
Visual/Verbal	7.00	2.60	4.17	4.39	4.154 (p=0.053)
Sequential/Global	0.28	4.94	0.00	2.89	0.031

Note: *p<0.05, **p<0.01

Relationships between working memory measures and other learning measures

Table 2.6 shows correlation between the four memory measures. The correlation was calculated to investigate whether the relationship between these measures were robust as predicted in previous research using the AWMA (Alloway & Gathercole, 2006; Alloway et al., 2008, 2009; Gathercole & Alloway, 2008). A series of parametric Pearson's Correlation Coefficients (*r*) was utilised. Table 2.7 shows significant correlations between working memory and study skills measures. This correlation was calculated to investigate the relationship between the four memory measures and the study skills variables.

Table 2.6 Correlation between standardised scores from AWMA

Measure	1	2	3	4
AWMA				
1. Verbal STM	1	0.500**	0.371*	0.052
2. Verbal WM		1	0.598**	0.353*
3. Visuo STM			1	0.361*
4. Visuo WM				1

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.

*** correlation is significant at the 0.01 level (1-tailed)*

** correlation is significant at the 0.05 level (1-tailed)*

Table 2.7 Significant correlation between working memory and study skills measures

Measure	Anxiety	Motivation	Self-testing	Time Management
AWMA				
Verbal STM	0.462*			
Verbal WM	0.609**	-0.394*		
Visuo STM	0.433*			
Visuo WM				

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.

*** correlation is significant at the 0.01 level (1-tailed)*

** correlation is significant at the 0.05 level (1-tailed)*

2.3.6 Summary

Study 1A has explored the differences and correlations between working memory variables and learning and study skills variables. Statistically significant differences between the dyslexic and non-dyslexic group were identified and the significant relationships between the two measures of both groups were investigated. The findings that emerged from the dyslexic group in Study 1A concur with previous literature (Jefferies & Everatt, 2003; Wilson & Lesaux, 2001) and add value to the limited working memory research on dyslexic adult learners. Interpretation of the findings presented in this chapter, and with the knowledge of the literature presented in Chapter 1, will be discussed again in the final chapter (Chapter 5).

Limitations to this initial study is the small number of participants (N=26 with 12 from the dyslexic group), that limit the statistical analysis. One reason is that there were not many individuals who were having problems in learning that decided to continue their study to postsecondary levels. According to a government research in the UK, individuals who were having problems early in schools and were identified as having dyslexia difficulties are much more likely to underachieve at GSCE levels and to leave education at 16 years old. There is a need to have early identification and intervention of learning difficulties in children and adolescent to improve the mental capacity and wellbeing of the individual specifically and the society as a whole (Foresight Mental Capacity and Wellbeing Project, 2008).

Study 1A was developed to investigate the working memory profile and learning strategy and study skills of college students with dyslexia. Findings from this experiment indicated that these students performed significantly worst in verbal short term memory, verbal working memory as well as in the visuospatial short term memory assessment compared to their peers who self-declared to have no learning difficulties. The dyslexic students' study skills were also found to be significantly different from the comparison group where the former group reported lower anxiety scores which were related to difficulty in focusing attention on task-relevant thoughts and behaviours. Overall, results from Study 1A managed to replicate previous findings on dyslexic performance on working memory as well as added strength to few adult dyslexic studies in this area.

Therefore, the next step of this research is to extend the current study and method to adult learners at the university level (Study 1B) which will be explained in the next section.

2.4 Study 1B

Study 1B is an extension of study 1A with replication of tasks and procedures as explained in Study 1A; however recruitment of dyslexic students were focused on university population. University students with and without dyslexia were compared in the working memory and other cognitive measures. Participants will also answered study skills and learning styles questionnaires to identify their learning and study strategies and learning tendencies. Study 1B was designed to further investigate whether the differences found in working memory profile of students 16-20 years old with and without dyslexia as well as their learning and study strategies still persist when they entered university. Again, the main focus of the study is whether there is any difference in the working memory profile and learning and study strategies of adult learners with and without dyslexia. The second aim is to discover if there is any relationship between the cognitive measures and learning and study skills, in order to get a better understanding of the role of working memory and study strategies in learning. It is expected that students with dyslexia in university will also reflect similar working memory profile as the college students with deficit in their verbal working memory while having a different study skills compared to students with no learning difficulties. The last section of this chapter will also discuss the analyses and findings of combining the data from the two studies on adult dyslexic learners (Study 1A & Study 1B).

2.4.1 Method

A total of 32 individuals participated in this study. Students with dyslexia *(n=14)* and students with no learning disabilities *(n=18)* were recruited from one of the top higher learning institutions in the United Kingdom. Students with dyslexia were selected from the disability services and through poster and email announcement in the university. Recruitment was also done via the Psychology electronic registration for participant interested in the research (PEEBs). Participants were then assigned to the dyslexic group if they were able to provide a current educational psychological assessment stating dyslexia as one of their major learning problems. Participants who reported having no learning disabilities were assigned to the comparison group. Although we advertised the research to attract participants to be involved in this study, the sampling of participants was a non-probability, convenience and purposive sampling. The 14 students (3 male and 11 female) that made up our Dyslexic group were in the age range between 19 to 30 years old; Mean (SD) age: 22.5 (3.10), while the comparison group consists of 3 male and 15 female students with an age range between 18 to 22 years old; Mean (SD) age: 20.1 (1.10). Both groups were matched as closely as possible in terms of age and gender. In terms of field of study, 21% of the dyslexic group was from the Chemistry Department and 14% from the Nursing Department while more than half of the participants in the control group were from the Psychology Department (55%). Students from History, Economics, Music, English literature and Environment each constitute a small percentage (5-7%) in the groups.

Based on the psychological assessment report, students in the dyslexic group were mostly diagnosed with mild to moderate dyslexia. Almost all of them were found to be of high overall intelligence with high verbal and non-verbal intellectual abilities. Most weakness or problems were related with reading accuracy, comprehension, and speed as well as spelling and writing large number of texts/reports, whereas, some dyslexic students were reported to have exceptionally high non-verbal/ visual abilities (attention to visual detail). Table 2.7 provides a summary of scores on reading & spelling from WAIT-II and general ability in verbal and non-verbal tasks from WAIS-III on dyslexic students that was reported in their psychological assessment report.

Wechsler Individual Achievement Test, Second Edition (WIAT-II) is an individually-administered battery used to assess reading, mathematics, written language, and oral language of individuals (Wechsler, 2005). While the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) was administered to individuals to assess intellectual abilities. The Verbal Comprehension Index provides an overall measure of verbal reasoning and understanding and is assessed via questions that are both asked and answered orally. The Perceptual Organisation Index measure nonverbal skills and is assessed by using pictures and patterns. Both scores are used to represent an individual intelligence scale.

Table 2.8 Mean standard scores on reading, spelling and general ability for the dyslexic students based on their Psychological Assessment Report

		Age (years)	Reading (WAIT-II Word Reading)	Spelling (WIAT-II Spelling)	Verbal Comprehension Index (WAIS-III)	Perceptual Organisation Index (WAIS-III)
Dyslexic (n=14)	Mean	22.5	91.6	88.4	14.6	14.1
	sd	3.10	8.8	9.2	1.3	2.6
	range	19-30	83-110	77-103	13-17	9-19

Note: WAIS-III scores are scaled scores with standardised mean of 10 and a standard deviation of 3.

2.4.2 Task materials/ Research instruments

All the materials used in this study were the same materials used in Study 1A and the details of the instruments and the assessment tools has been described previously in this chapter.

2.4.3 Procedure

The testing took place in an experiment lab or a quiet room where participants were provided with a brief description of the study. They were asked to sign a consent form prior starting the tasks. Each participant will fill in basic demographic information which included name, age, gender, the year of study, A-level grades, the department and course that they took, and type of learning disabilities. The cognitive assessments, tasks and questionnaires were administered individually to all of the participants. The AWMA was presented first followed by WAIS-III. The questionnaires were then administered last. The testing lasted between 60-90 minutes depending on how the participants performed in the tasks. Following the completion of the testing session, participants were debriefed, and questions pertaining to the study were addressed. Participants were then given either payment or course credits for their participation in the study.

2.4.4 Ethical Issues

The same research approval was granted for this study. Refer to Appendix 1-3.

2.4.5 Result

The data collected from all of the participants were gathered and analysed using the Statistical Package for Social Sciences version 17 (SPSS 17). Multivariate Analysis of Variance (MANOVA) and correlation studies were completed and assumptions were met. Below are the details of the statistical result for each component that this study measures.

Working memory

In order to identify and investigate the working memory performance of the dyslexic and comparison group, a multivariate analysis of variance (MANOVA) was conducted to compare the two groups on the four memory measures. However, no group difference was found in the AWMA scores where the Wilks' Lambda was not significant, F (4, 27) =2.30, *ns (p=0.085;* partial $\eta^2 = 0.25$).However, the univariate analyses indicated one significant difference between the groups. Student with dyslexia had lower scores on the verbal working memory tasks, F (1, 30) = 9.67, $p<0.01$, partial $\eta^2=0.24$ compared to the group of students with no learning disabilities. Table 2.9 shows descriptive statistics for the working memory measures for both groups of students. The fairly large difference that exists between the means of both groups in the verbal working memory tasks (refer Table 2.9) indicates that something important is going on, so a larger sample size might be justified. The data thus supported the hypothesis that dyslexic group show poorer performance in the verbal working memory (specific impairment not global impairment in working memory).

Table 2.9 Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 1B)

	Non Dyslexic		Dyslexic		
Measure	*M*	*SD*	*M*	*SD*	*F*
AWMA					
Digit recall	102.8	18.79	90.78	18.70	3.249
Non word recall	99.33	16.44	96.78	14.59	0.208
Verbal STM	101.1	13.69	93.78	14.33	2.149
Listening recall	102.1	13.66	90.07	17.12	4.945*
Backwards digit recall	104.6	17.30	87.50	15.74	8.320**
Verbal WM	103.4	12.80	88.79	13.66	9.667**
Dot matrix	102.7	11.50	95.64	13.01	2.659
Mazes memory	101.3	13.52	94.57	7.822	2.721
Visuospatial STM	96.8	8.10	90.61	9.66	3.864
Odd one out	103.8	12.55	95.71	11.88	3.403
Spatial recall	101.5	15.80	96.62	11.81	0.928

Visuospatial WM	102.6	11.12	96.17	9.59	2.999

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.*p<0.05, **p<0.01

General cognitive abilities (Wechsler Adult Intelligence Scale)

The data on WAIS-III were analysed using the MANOVA to examine whether there is also differences between groups in performing other cognitive and general intelligence tasks. For the verbal and non-verbal tasks, an overall group difference was found where the Wilks' Lambda was significant, F (4, 27) = 4.674, p<0.05, partial η^2=0.41, with the univariate results showing the dyslexic students performing significantly better than the comparison group, F (1, 30) = 16.19, p<0.01, partial η^2=0.35, in the verbal information task which was a general question task as shown in Table 2.10. The scaled scores shown in Table 2.10 have a mean average of 10, with scores that range from 1 to 19. These scores are relative to the abilities of other individuals in the same age group. The short form WAIS-III subtest was intended to measure the general intelligence of these young adults and it seems that although dyslexic students have substantial deficit in their verbal working memory, their general knowledge was particularly high while having an overall above average scores for all other tasks as well.

Table 2.10 Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 1B)

	Non Dyslexic		Dyslexic		
Measure	*Mean*	*SD*	*Mean*	*SD*	*F*
WAIS-III					
Processing speed (Digit symbol coding)	11.33	3.125	10.36	3.342	0.723
Perceptual organisation (Block design)	11.72	2.696	13.57	3.204	3.143
Working memory (Mental Arithmetic)	11.78	2.579	11.28	0.914	0.461

Verbal comprehension (Information)	12.06	1.893	14.57	1.555	16.188**

Note: *p<0.05, **p<0.01

Learning and study skills performance

To examine whether the students with and without dyslexia differed on their learning strategies and study skills, scores on each LASSI subscales were analysed using MANOVA. For learning and study skills performance, an overall group difference was found where the Wilks' Lambda was significant, F (10, 21) = 2.911, p<0.05, partial η^2=0.58. Follow-up univariate analyses indicated 6 significant differences between the groups. Students with dyslexia reported lower scores on Anxiety, F(1,30) = 14.34, p<0.01, partial η^2=0.32 ; Concentration and attention, F(1,30) = 16.54, p<0.01, partial η^2=0.36; Motivation, F(1,30) = 4.97, p<0.05, partial η^2=0.14; Selecting main ideas, F(1,30) = 7.97, p<0.01, partial η^2=0.21; Time management techniques, F(1,30) = 5.13, p<0.05, partial η^2=0.15 and Test strategies, F(1,30) = 26.38, p<0.01, partial η^2=0.47 (Table 2.11). Thus, findings showed that the learning and study skills profile of students with dyslexia differ significantly with students with no learning disability. Figure 2.1 shows bar graphs indicating the mean scores for each study skills for both groups. Table 2.11 provides statistical data for each LASSI scale. Students with dyslexia reported to have high negative thoughts, beliefs and feelings about their abilities (anxiety) and to use ineffective main ideas techniques, time management and test taking strategies.

Table 2.11 Means and Standard Deviations of Measures of Learning Strategies and Study Skills by Disability Status (Study 1B)

		Non Dyslexic		Dyslexic		
Measure	*A*	*M*	*SD*	*M*	*SD*	*F*
LASSI						
Anxiety	0.828	26.50	6.06	18.50	5.74	14.34**
Attitude	0.661	30.17	4.22	30.00	5.35	0.010
Concentration	0.820	24.78	4.87	18.28	3.91	16.54**
Information Processing	0.694	27.61	4.94	28.21	4.15	0.14

Motivation	0.722	30.56	4.60	27.00	4.30	4.97*
Self-Testing	0.671	22.83	5.32	21.28	4.16	0.802
Selecting Main Ideas	0.921	28.22	6.92	21.21	7.02	7.97**
Study Aids	0.651	22.83	4.65	23.71	4.12	0.311
Time Management	0.817	23.94	6.06	19.28	5.37	5.13*
Test Taking	0.840	30.00	4.35	21.71	4.75	26.38**

Note: LASSI = Learning and Study Skills Inventory (Weinstein et. al, 2002); STM = short-term memory; WM = working memory. *p<0.05, **p<0.01

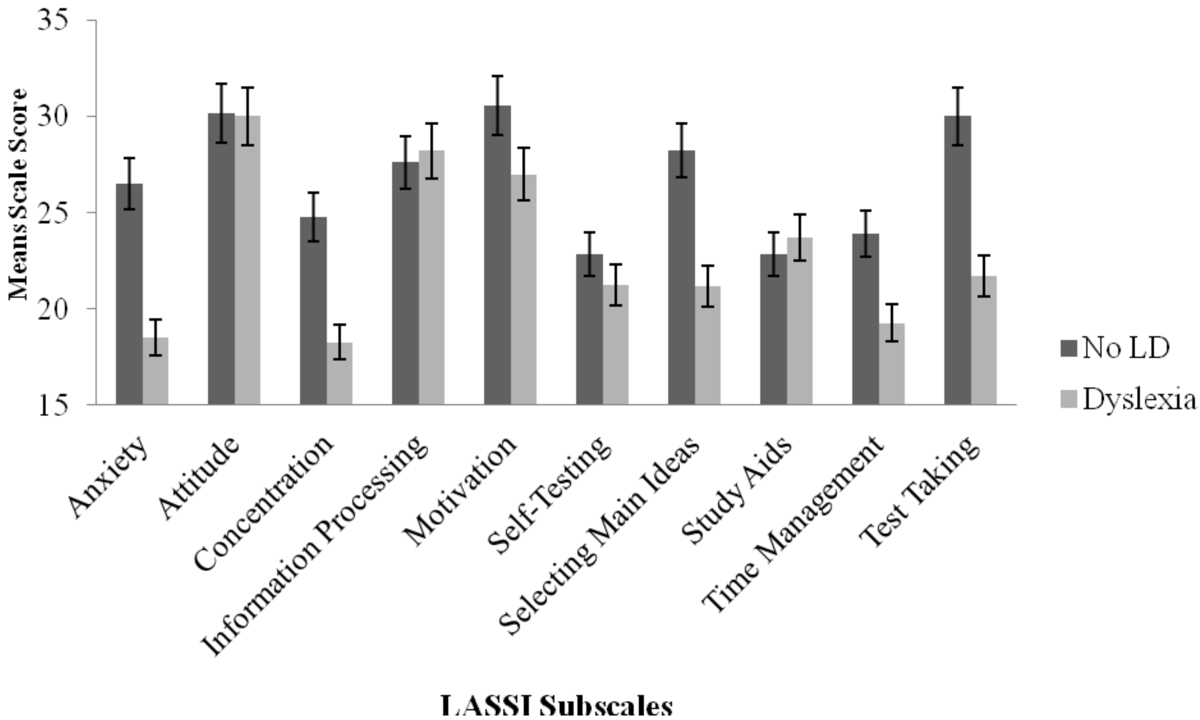


Figure 2.1 Mean scores for each subscales of LASSI by disability status

Learning preferences/tendency

A MANOVA was also conducted on the ILS converted scores. There was no significant overall group difference between dyslexic and non-dyslexic students on the learning style tendencies, F (4, 27) = 0.828, *ns (p=0.519;* partial η^2=0.12). Table 2.12 illustrates univariate analyses showing no significant difference between dyslexic students and the control group in all dimensions of learning styles.

Table 2.12 Descriptive Statistics for the Learning preference (ILS) as a Function of Group (Study 1B)

	Non Dyslexic		Dyslexic		
Measure	*Mean*	*SD*	*Mean*	*SD*	*F*
ILS					
Active/Reflective	-1.78	4.558	-0.28	5.298	0.733
Sensing/Intuitive	-1.11	5.200	-0.43	5.787	0.123
Visual/Verbal	1.56	5.607	4.43	3.877	2.672
Sequential/Global	-0.67	3.896	-1.71	3.010	0.677

Note: *p<0.05, **p<0.01

Relationship between Working Memory and Learning and Study Skills

One of the objectives of Study 1B is to investigate whether there is any relationship between working memory performance and the learning and study skills that the students adopted. In order to answer this question, correlations between working memory measures and learning strategies for the all the participants in Study 1B were computed as shown in Table 2.13.

Table 2.13 Correlations between Working Memory measures and Learning Strategies for All Participants (Study 1B)

	AWMA			
Measure	Verbal STM	Verbal WM	Visuo-spatial STM	Visuo-spatial WM
LASSI				
Anxiety	0.328*	0.565**	0.258	0.257
Attitude	0.349*	0.214	0.092	0.192
Concentration	0.253	0.278	0.445**	0.446**
Information Processing	-0.044	-0.150	-0.068	-0.232
Motivation	0.172	0.159	0.120	0.347*

Self-Testing	0.168	0.064	0.080	-0.027
Selecting Main Ideas	0.172	0.359*	0.351*	0.189
Study Aids	0.124	-0.158	-0.050	0.127
Time Management	0.182	0.129	0.016	0.096
Test Taking	0.271	0.439**	0.281	0.272

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); LASSI = Learning and Study Strategies Inventory (Weinstein et. al, 2002). STM = short-term memory; WM = working memory; *p<0.05. **p<0.01.

Based on Table 2.13, there exist several positive relationships between working memory variables and study strategies for all the participants. Scores on anxiety management was associated positively with both measures of verbal short-term memory and working memory while scores on attitude was linked positively with measures of verbal short-term memory. Both measures of visuospatial short-term and working memory were related positively with scores on concentration while motivation scores was found to be closely related with only performance on visuospatial working memory tasks. Selecting main ideas scores was connected positively with verbal working memory and visuospatial short-term memory tasks performance and finally Test-taking strategies scores was positively associated with only the verbal working memory measures.

In order to identify which variables are related with each other, a factor analysis on all the cognitive measures and LASSI was also conducted. The method of extraction used was Principal Component Analysis with Varimax rotation. The factor analysis on all 14 items were conducted based on the Kaiser-Meyer-Olkin measure of sampling adequacy which was 0.54 which is within the recommended value, and Bartlett's test of sphericity was significant (χ^2 (91) = 216.22, p < .01), both indicating that factor analysis may be useful with the data (Field, 2005). An adequate value for KMO test statistic is .5-.7 (mediocre) but ideally this value should be higher (Field, 2005; Hutcheson & Sofronium, 1999). The result of the factor analysis indicated that there were 6 factors with eigenvalues greater than 1.0. Based on the scree plot, a two factor solution was deemed appropriate. Factor 1 was labelled "General learning and study skills" and accounted for 30% of the variance, Factor 2 was labelled "Working memory" and accounted for 14% of the variance while a third factor accounted for 13% of the variance (Table 2.14). The fourth, fifth and sixth factors had eigenvalues of just over one, each factor explaining 9% to 8% of the variance. A MANOVA was also conducted on the factor scores and the Wilks' Lambda was significant at F (6, 25) =4.79, p<0.01, indicating an overall group difference. Results from tests of between-subjects effects was significant for the first factor at p<0.01.

Table 2.14 Factor loadings for the LASSI and AWMA

Item	Factor loading (1)	Factor loading (2)	Factor loading (3)	Factor loading (4)	Factor loading (5)	Factor loading (6)
Selecting main ideas	0.908					
Test strategies	0.875					
Anxiety	0.685					
Concentration	0.669			0.402		
Verbal WM		0.900				
Visuo-spatial STM		0.802				
Verbal STM		0.730				
Visuo-spatial WM		0.543				
Time management techniques			0.917			
Motivation			0.808			
Use of support techniques				0.901		
Attitude				0.456	0.541	
Information processing					0.891	
Self-testing						0.930

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); LASSI = Learning and Study Strategies Inventory (Weinstein et. al, 2002). STM = short-term memory; WM = working memory. For all between-group comparisons, an alpha level of 0.05 was used to evaluate statistical significance.

A multivariate analysis of covariance (MANCOVA) was also conducted on the LASSI data scores between the two groups of students controlling each working memory measures. No significant differences were found when verbal short-term memory, verbal working memory, visuospatial short-term memory and visuospatial working memory were assigned as covariate (F (10, 20) = 1.039, 1.249, 0.56, 1.01, *ns* respectively). However, when controlling for each memory measures, although no overall group difference was found, significant group differences were found on anxiety, concentration, selecting main ideas and test taking strategies.

2.4.6 Summary

Study 1B explored the differences and correlations between working memory variables and learning and study skills variables between university students. Due to the small number of participants, no significant difference between dyslexic and non-dyslexic group in the working memory performance was found. However, looking at the mean between the dyslexic and non-dyslexic students, there was a fairly large difference between the groups of participants. Significant findings were found in the student learning and study skills which replicate findings from Study 1A. Overall interpretation of results from study 1B will be discussed and explored further in Chapter 5.

Both Study 1A and Study 1B have limitation which was the small number of participants. In the next section, we will analyse the combined data of both studies since both studies have the same purpose and objectives of the research. Participants in both studies were between the age of 16-30 years old and the data were collected within a year of each other. The purpose of combining the data from the two studies was to obtain stronger significant findings on the overall measure of working memory, learning styles and study strategies of university and college students with dyslexia.

2.5 Study 1A and Study 1B

University and college students with dyslexia and typical students with no reported learning disabilities were recruited in Study 1A and Study 1B. They completed a series of cognitive and intelligence tests to measure their short term memory and working memory, and answered two self-report questionnaires relating to study skills and learning preferences.

2.5.1 Method

Participants

A total of 58 participants' data were collected via Study 1A and Study 1B. Students with dyslexia *(n=26)* and students with no learning disabilities *(n=32)* were recruited from colleges and university in Leeds and York. Students with dyslexia were recruited from the disability services, learning support centers and through poster and email announcement in the university and colleges. Participants were then assigned to the dyslexic group if they were able to provide a current educational psychological assessment stating dyslexia as one of their major learning problems. Participants who reported no learning disabilities were assigned to the comparison group. Table 2.15 represents the demographic of all the participants by group.

Table 2.15 Age, gender ratio of the groups of students tested

	Dyslexic	Non Dyslexic
No. of participants	26	32
Female, male	17, 9	19, 13
Age range	16-30	16-22
Mean age in years *(SD)*	20.46 *(3.29)*	18.53 *(1.61)*

2.5.2 Task materials and procedures

The materials, tasks and procedures were as described in Study 1A and Study 1B.

2.5.3 Result

The data collected from all of the participants were gathered and analysed using the Statistical Package for Social Sciences version 17 (SPSS 17). Again Multivariate Analysis of Variance (MANOVA) and correlation studies were completed and assumptions were checked. Below are the details of the statistical result for each component that this experiment measures.

Working memory

Based on the combined data, a multivariate analysis of variance (MANOVA) was conducted to compare the two groups on the four memory measures. As predicted a significant group difference was found in the working memory performance where Wilks' Lambda was significant at F (4, 53) = 4.91, $p<0.01$, partial $\eta^2=0.27$. Further univariate analyses indicated significant difference between the groups on all of the four memory measures; F (1, 56) = 6.19, $p<0.05$, partial $\eta^2=0.10$ for verbal short-term memory, F (1, 56) = 19.70, $p<0.01$, partial $\eta^2=0.26$ for verbal working memory, F (1, 56) = 9.03, $p<0.01$, partial $\eta^2=0.14$ for visuospatial short-term memory, and F (1, 56) = 5.86, $p<0.05$, partial $\eta^2=0.10$ for visuospatial working memory. Table 2.16 provides descriptive statistics for all subtests of working memory used in the study.

Table 2.16 Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 1A & 1B)

	Non Dyslexic		Dyslexic		
Measure	*M*	*SD*	*M*	*SD*	*F*
AWMA					
Digit recall	98.34	15.99	86.31	15.39	8.401**
Non word recall	96.66	14.04	92.11	15.61	1.360
Verbal STM	97.50	12.06	89.21	13.28	6.190*
Listening recall	99.22	12.67	87.73	14.08	10.676**
Backwards digit recall	100.92	14.78	85.27	12.86	18.040**
Verbal WM	100.07	11.63	86.50	11.52	19.697**
Dot matrix	98.56	12.92	91.19	14.82	4.089*
Mazes memory	100.81	12.74	92.46	10.64	7.126*
Visuospatial STM	96.75	9.34	88.69	11.08	9.035**
Odd one out	101.92	19.63	92.08	12.66	4.852*
Spatial recall	99.16	12.90	94.03	12.24	2.373

Visuospatial WM	100.54	12.24	93.05	11.02	5.863*

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.*p<0.05, **p<0.01

General cognitive abilities (Wechsler Adult Intelligence Scale)

The data on WAIS-III for all participants were analysed using the MANOVA to examine whether there is also differences between groups in performing other verbal and nonverbal tasks. However, no significant group difference was found, *F* (4, 53) = 2.356, *ns* (*p=0.065;* partial η^2=0.15). Table 2.17 illustrates the means, standard deviations and univariate analyses on both the general cognitive tasks and learning styles for both groups.

Table 2.17 Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 1A & 1B)

	Non Dyslexic		Dyslexic		*F*
Measure	*Mean*	*SD*	*Mean*	*SD*	
WAIS-III					
Processing speed (Digit-symbol	10.19	3.042	8.85	3.641	2.338
Perceptual organisation (Block design)	11.16	2.653	11.92	3.346	0.948
Working memory (Mental arithmetic)	10.03	3.095	9.73	2.691	0.152
Verbal comprehension (Information)	10.22	2.959	11.54	4.159	1.988

Note: **p*<0.05, ***p*<0.01

Learning and study skills performance

To examine whether the students with and without dyslexia differed on their learning strategies and study skills, scores on each LASSI subscales were analysed using MANOVA. As predicted, an overall group difference was found in terms of students' learning and study skills where the Wilks' Lambda was significant, *F* (10,

42) = 4.267, p<0.01, partial η^2=0.48. Follow-up univariate analyses indicated 5 significant differences between groups. Students with dyslexia reported lower scores on Anxiety, F(1,56) = 37.09, p<0.01, partial η^2=0.40; Concentration and attention, F(1,56) = 11.96, p<0.01, partial η^2=0.18; Selecting main ideas, F(1,56) = 8.88, p<0.01, partial η^2=0.14; Time management techniques, F(1,56) = 5.23, p<0.05, partial η^2=0.09, and Test strategies, F(1,56) = 18.22, p<0.01, partial η^2=0.25 (Table 2.18). Again, students in the dyslexic group were reported to have high anxiety levels while using less effective techniques in identifying important information, time management and test preparation and test strategies.

Table 2.18 Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by Disability Status (Study 1A & 1B)

	Non Dyslexic		Dyslexic		
Measure	*M*	*SD*	*M*	*SD*	*F*
LASSI					
Anxiety	26.28	5.70	17.73	4.80	37.087**
Attitude	28.75	5.09	28.08	6.77	0.186
Concentration	23.00	5.35	18.58	4.14	11.957**
Information Processing	26.09	5.35	27.42	4.91	0.952
Motivation	28.34	5.88	26.00	4.77	2.689
Self-Testing	21.16	5.96	20.69	5.39	0.095
Selecting Main Ideas	26.84	6.41	21.84	6.28	8.879**
Study Aids	23.62	4.25	24.19	3.51	0.297
Time Management	22.19	5.82	19.04	4.35	5.228*
Test Taking	27.62	5.20	22.12	4.47	18.223**

Note: LASSI = Learning and Study Skills Inventory (Weinstein et. al, 2002); STM = short-term memory; WM = working memory. *p<0.05, **p<0.01

Learning preferences/tendencies

A MANOVA was also conducted on the combined ILS converted scores. There was no significant overall group difference between dyslexic and non-dyslexic students on the learning style tendencies, F (4, 53) = 0.428, *ns* (*p=0.788*; partial η^2=0.03) as shown in Table 2. 19.

Table 2.19 Descriptive Statistics for the Learning preference (ILS) as a Function of Group (Study 1A & 1B)

Measure	Non Dyslexic		Dyslexic		*F*
	Mean	*SD*	*Mean*	*SD*	
ILS					
Active/Reflective	0.75	4.865	0.00	5.161	0.323
Sensing/Intuitive	-0.56	4.621	-0.23	5.125	0.067
Visual/Verbal	3.94	5.254	4.31	4.037	0.087
Sequential/Global	-0.25	4.332	-0.92	3.071	0.445

Note: *$p<0.05$, **$p<0.01$

Relationship between Working Memory and Learning and Study Skills

One of the objectives of this experiment is to investigate whether there is any relationship between working memory performance and the learning and study skills that the students adopted. In order to answer this question, correlations between working memory measures and learning strategies for the all the participants in study 1A and study1B were computed as shown in Table 2.20.

Table 2.20 Correlations between Working Memory measures and Learning Strategies for All Participants (Study 1A & Study 1B)

Measure	AWMA			
	Verbal STM	Verbal WM	Visuo-spatial STM	Visuo-spatial WM
LASSI				
Anxiety	0.377**	0.576**	0.345**	0.250
Attitude	0.340**	0.198	0.179	0.036
Concentration	0.198	0.132	0.163	0.210
Information Processing	0.071	-0.140	-0.198	-0.263*
Motivation	0.242	0.117	-0.128	0.193
Self-Testing	0.125	-0.023	-0.128	0.193

Selecting Main Ideas	0.201	0.287*	0.225	0.199
Study Aids	0.008	-0.214	-0.136	-0.007
Time Management	0.223	0.098	0.013	0.090
Test Taking	0.316*	0.410**	0.127	0.256

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); LASSI = Learning and Study Strategies Inventory (Weinstein et. al, 2002). STM = short-term memory; WM = working memory; *$p<0.05$. **$p<0.01$.

Anxiety management was associated positively with both measures of verbal memory as well as with visuospatial short term memory while attitude was linked positively with verbal short-term memory. Information processing skill was negatively correlated with visuospatial working memory. Selecting main ideas was connected positively with verbal working memory and finally Test-taking strategies were associated with both verbal short term memory and working memory.

A multivariate analysis of covariance (MANCOVA) was also conducted on the LASSI data score between the two groups of students controlling each working memory measures. An analyses using MANCOVA can control other effects of variation (working memory) in order to increase statistical power and to ensure an accurate measure of the true relationship between independent variable (learning disability group difference) and dependent variable (Study skills). A significant group difference was found for LASSI with verbal STM as covariate with $F(10,46)=3.329$, $p<0.01$, LASSI with verbal WM as covariate with $F(10,46)=2.329$, $p<0.05$, LASSI with visuospatial STM as covariate with $F(10,46)=3.368$, $p<0.01$ and LASSI with visuospatial WM as covariate with $F(10,46)=3.478$, $p<0.01$. Further univariate analyses on each MANCOVA found significant group differences mainly on anxiety, concentration, selecting main ideas and test taking strategies. Overall the data shows a group difference between the dyslexic and non-dyslexic group in learning and study skills while controlling the working memory measures especially in managing anxiety, concentration, techniques on selecting main ideas and test taking.

2.5.4 Summary

Findings based on the combined data showed that there was a significant difference between the dyslexic and the non-dyslexic group in working memory performance and learning and study skills. The dyslexic group performed significantly poorly in all of the working memory tasks especially on the verbal working memory tasks (Table 2.16). However, looking separately between the college and university students' data on their working memory profiles, the college students in the dyslexic group scored one standard deviation below the average mean score (< 85) on both verbal short-term memory (M = 83.87) and verbal working memory (M= 83.83) tasks, indicating a deficit in these area of working memory (Table 2.2). However, the dyslexic group from the university's data performed above 85, although not reaching the average population score (100) in all the memory tasks (Table 2.9).

While, we cannot compare directly these two sets of data, it seems to show a group differences between the college and university dyslexic students in their working memory performance. One explanation might be that only those dyslexic students who have found ways of being a successful learner make it to the university. It would take a longitudinal study to establish the developmental changes (cognitive, psychosocial) that happened between the college and university stages in dyslexic individuals that would resulted in the differences.

The combined results showed as well that the dyslexic group reported to use less effectively the following study skills compared to students with no learning disabilities; anxiety, concentration, time management, selecting main ideas, and test taking strategies (refer to Table 2.18). These five LASSI scales are related with the skill, will, and self-regulation component of strategic learning. Results indicated that the dyslexic students were more worried of their school and academic performance, have weakness in managing their time and concentration to meet the learning demands for class or assignments, were less able to select important information from less important information, and using test preparation and test taking strategies less effectively (Weinstein, Palmer, & Shulte, 2002).

One limitation that was found in Study 1B was on the disproportion of discipline between the dyslexic and group of student with no learning disabilities. Science students were mostly represented in the dyslexic group while most non science students were allocated in the non-dyslexic group. Interestingly this limitation prompted us to investigate the working memory performance, study skills and learning styles of non-dyslexic adult learners and analysed by comparing between disciplines which will be discussed in the next chapter (Chapter 3).

CHAPTER THREE

WORKING MEMORY AND SCIENCE

3.1 Introduction

The findings gathered from Study 1A and Study 1B (Chapter 2) support previous discovery with regards to dyslexia (learning disability) and working memory performance. Although many of the learning disability research focused on children in the early school years, these studies added support to limited research on adult dyslexia where deficits in the verbal working memory still persists even in intelligent young adults. It also appears that students with dyslexia have different study skills profile than their peers with no learning disabilities. The disparities between these groups of student are more on managing anxiety (the degree in which the students are able to cope with debilitating thoughts and worrying about academic performance), selecting main ideas technique, concentration (focusing attention on learning related activities), time management and test taking strategies. Correlation analysis between working memory performance and study skills indicate significant relationships between these two measures. Students who performed poorly in verbal short-term and verbal working memory tasks were found to report lower scores on the above study skills as well. It is possible to speculate that the differences found in learning and study skills were associated with differences in the groups working memory profiles.

This chapter will introduced the first of the final two studies investigating working memory performance, study skills and learning styles of non-dyslexic adult learners, comparing the students based on the discipline or subjects that they took in university. Study 2A reported here was designed to investigate the working memory strength and weaknesses of typical university students (those who reported having no learning disabilities), their learning styles and study skills and compared the data in terms of disciplines (science and humanistic students). While the final study (Study 2B) is an extension of Study 2A with larger pool of participants and additional measures and tasks to further analyse the findings. Introduction to the experiment followed by the methodology adopted in Study 2A will be explained in the subsequent sections. This will be followed by data analysis and discussion of findings in relation to working memory profiles and learning and study skills at the end of the chapter.

3.2 Aims and Hypotheses

As previously stated in chapter one, working memory has been widely established to be a reliable predictor of academic success. Research has also shown working memory to be a good predictor in science attainment (Bull, Johnson & Roy, 1999; Gathercole et al., 2004; Jarvis & Gathercole, 2003). Students with a low working memory capacity is related with a weaker understanding of science knowledge where as high working memory capacity students performed better in science and have a more positive attitude towards learning science (Chen & Whitehead, 2009; Hussein & Reid, 2009; Reid, 2009).

Visuospatial superiority was also linked to characterized science students as well as those with dyslexia. The purpose of this study is to investigate the component of working memory as well as learning and study strategies of students according to discipline. The main focus is on whether there is any difference in the working memory profile and learning and study strategies of students in Science and Non science departments. The second aim is to discover if there is any relationship between the cognitive measures and learning and study skills, in order to get a better understanding of the role of working memory and study strategies in learning. A comparison of working memory profile of science students with dyslexic will also be discussed.

Below are specific hypotheses generated to investigate the relationship between working memory, study skills, learning preferences and science discipline:

1. Science students will show significant differences in their verbal short-term and verbal working memory performance when compared to humanities students.

2. There will be significant differences between science and humanities group in their visuospatial short-term and visuospatial working memory performance.

3. There will be no significant difference between science and humanities group in general cognitive ability tasks (Wechsler Adult Intelligence tests)

4. Science students will show significant differences in their reported study skills when compared to humanities students.

5. There will be significant differences between science and humanities group in their learning style preferences.

6. There is a relationship between working memory and study skills in adult learners in higher education.

3.3 Study 2A

University students in science and humanities departments were recruited and they completed a series of cognitive and intelligence tests to measure their short term memory and working memory, and two self-report questionnaires relating to study skills and learning preferences. For postsecondary institutions, it is increasingly important to further understand the cognitive limitations and compensatory strategies of students in order to provide appropriate instruction in learning strategies and study approaches to maximize their academic success.

3.2.1 Method

Participants

A total of 60 students from one of the higher learning institutions in the United Kingdom participated in this study. Students who were from the Science Department such as Biology, Chemistry, Engineering and Physics *(n=30)* were assigned to the Science group consisting of 24 female and 6 male students with an age range between 18-27 years old (Mean (*SD*) = 20.3 (*2.5*)). While students from the Arts Department such as Literature, History, Philosophy & Economics and Sociology were assigned to the Humanistic group *(n=30)* with 19 female and 11 male with an age range between 18-25 years old (Mean (*SD*) = 20.1 (*1.8*)).

3.2.2 Tasks materials

All of the participants were administered cognitive and intelligence tasks to measure their short-term and working memory as well as other cognitive abilities. Two self-reported questionnaires were then completed that measures participants' study skills and learning preferences or tendencies. All the materials used in Study 2 were the same materials used in previous studies (Study 1A & Study 1B) which have been described in detail in Chapter 2.

3.2.3 Procedure

The testing of the study took place in a quiet room where participants were provided with a brief description of the study and then asked to sign a consent form prior starting the tasks. Each participant will fill in basic demographic information which included name, age, gender, current year of study, A-level grades, the department and course that they took in university. The cognitive assessments, tasks and questionnaires were administered individually to all of the participants. The AWMA was presented first followed by WAIS-III. The questionnaires were then administered last. The testing lasted between 60-90 minutes depending on how the participants performed in the tasks. Following the completion of the testing session, participants were debriefed, and questions pertaining to the study were addressed. Participants were then given either payment or course credits for their participation in the study.

3.2.4 Ethical Issues

The Departmental Ethics Committee, Department of Psychology from the University of York approved the research proposal for Study 2 (Appendix 4). The participants of the study were recruited and assessed based on the outline and description given in the proposal. Information sheet, consent forms and appropriate de-briefing were given to the participants. These are available in Appendix 1 and Appendix 2. In these documents, the participants were informed about the purpose of the study and procedures of the assessment. They were also assured about the right to refuse or withdrawn from the study at any time without penalty. Ensuring the confidentiality of participants' data during the process of data collection, data analysis and reporting of results were also explained and implemented.

3.2.5 Result

The following section will described the results of the analyses of Study 2A. Inferential and descriptive statistical techniques were performed on all variables of the data to address the research questions and hypotheses of the study using SPSS version 17. Multivariate analysis of variance (MANOVA) was calculated to determine if there were significant differences between the science and humanistic groups in terms of their working memory performance, general cognitive tasks, study skills and learning preferences. Lastly, correlational analysis was performed to examine the relationship between working memory and study skills for both groups.

Working memory

A multivariate analysis of variance (MANOVA) was conducted to compare the two groups on the four memory measures. The Wilks' Lambda was significant, F (4,55) = 4.93, $p<0.01$, partial $\eta^2=0.28$ indicating an overall group difference in AWMA scores. Further univariate analyses indicated 2 significant differences between the groups. Table 3.1 shows mean and standard deviation of each working memory tasks for both groups of students. Student majoring in science courses had lower scores on both verbal short term memory, F (1,58) = 14.42, $p<0.01$, partial $\eta^2=0.20$ and verbal working memory tasks, F (1,58) = 6.15, $p<0.05$, partial $\eta^2=0.10$. However, no significant difference was found between the groups in the visuospatial component of working memory.

Table 3.1 Descriptive Statistic for the Working Memory Tasks as a Function of Group (Study 2A)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
AWMA					
Digit recall	108.10	16.176	98.40	14.148	6.112*
Nonword recall	113.06	14.339	99.62	13.608	13.852**
Verbal STM	110.50	13.637	98.91	9.652	14.423**
Listening recall	101.47	13.561	99.60	11.239	0.337
Backward digit recall	108.77	16.472	96.17	15.001	9.595**
Verbal WM	105.05	12.554	97.67	10.411	6.147*
Dot matrix	98.83	16.244	102.53	14.440	0.869
Mazes memory	97.53	11.494	99.93	11.419	0.658
Visuospatial STM	97.13	12.470	99.15	10.220	0.469
Odd one out	103.57	13.790	105.76	11.369	0.453
Spatial recall	100.76	14.092	100.73	13.824	0.000
Visuospatial WM	102.11	11.525	103.13	10.814	0.124

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.*p<0.05, **p<0.01

General cognitive abilities (Wechsler Adult Intelligence Scale)

MANOVA was also conducted on WAIS-III scores between the 2 groups. The Wilks' Lambda was significant, $F(4,55)=2.762$, $p<0.05$, partial $\eta^2=0.17$ indicating an overall group difference in WAIS-III scores. Further univariate analyses indicated one significant difference between the groups in working memory task, where science students scored lower in the mental arithmetic task compared to the humanistic group, $F(1,58)=5.513$, $p<0.05$, partial $\eta^2=0.09$. Table 3.2 shows descriptive statistics for WAIS-III for both groups of students.

Table 3.2 Descriptive Statistic for the Cognitive tasks (WAIS-III) as a Function of Group (Study 2A)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
WAIS-III					
Processing speed (Digit-symbol coding)	11.13	2.968	12.16	2.983	1.809
Perceptual Organization (Block design)	12.43	1.959	12.56	2.541	0.052
Working memory (Mental arithmetic)	12.83	3.040	11.20	2.295	5.513*
Verbal Comprehension (Information)	13.56	1.813	12.76	2.314	2.221

Note: WAIS-III = *Wechsler Adult Intelligence Scale –III ,* *p<0.05, **p<0.01

Learning and study skills performance

To examine whether the students in different disciplines varied on their learning strategies and study skills, scores on each LASSI subscales were analysed using MANOVA. For LASSI, The Wilks' Lambda was not significant, $F(10,49)$ = 0.678, *ns* (p=0.740; partial η^2=0.12). Univariate analyses also showed no significant difference between the groups in all sub scales of learning strategies. Table 3.3 provides descriptive statistics of each LASSI scale for each group. However, humanistic students reported to have slightly lower scores on time management techniques compared to the science students although not significant at p=0.85. Thus, based on the statistical findings, the study shows that the learning and study skills profile of these students did not differ according to the course that they took.

Table 3.3 Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by group (Study 2A)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
LASSI					
Anxiety	27.13	5.82	25.70	7.83	0.646
Attitude	31.26	3.13	31.73	3.97	0.255
Concentration	25.16	5.49	25.56	5.11	0.085
Info. Processing	28.00	4.25	27.06	5.99	0.484
Motivation	29.96	5.72	30.93	4.79	0.502
Self-Testing	21.86	4.78	23.53	6.75	1.216
Selecting Main Ideas	27.80	5.59	28.73	5.96	0.391
Study Aids	23.13	4.26	23.53	5.81	0.092
Time Management	21.80	5.93	24.66	6.74	3.053
Test Taking	29.60	5.51	30.33	4.34	0.327

Note: LASSI = Learning and Study Skills Inventory (Weinstein et. Al, 2002); *p<0.05, **p<0.01

Learning preference/tendency

The data on learning preferences was also analysed using MANOVA to investigate the differences in learning tendencies between groups. Based on Table 3.4, no overall group difference was found, $F(4,55)=1.546$, *ns (p=0.202;* partial $\eta^2=0.10$). Univariate analyses indicated one significant difference in sensing versus intuitive learning preference, $F(1,58)=5.645$, $p<0.05$, partial $\eta^2=0.09$, where humanistic students lean more to intuitive learning while science students more on sensing. Sensing learners tend to like learning facts, solving problems with well-established methods, patience with details, more practical and tend to go for courses that have connections to the real world while intuitive learners prefer to discover possibilities and relationship (Felder & Brent, 2005).

Table 3.4 Descriptive Statistic for the Learning preference (ILS) as a Function of Group (Study 2A)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
ILS					
Active/Reflective	-.93	5.185	-1.00	4.000	0.003
Sensing/Intuitive	-2.33	5.761	.87	4.606	5.645*
Visual/Verbal	.27	5.789	2.27	4.471	2.243
Sequential/Global	-.33	4.146	.67	4.459	0.809

3.2.6 Summary

Study 2A was designed to investigate working memory performance and learning and study skills of typical university students in different disciplines. Findings from this experiment showed that students in the science group performed significantly worst in both verbal short-term memory and verbal working memory tasks compared to the humanistic group. In terms of their learning strategies and study skills, there were no significant differences between the two groups, however, the science group was found to lean towards a sensing type of learner while the humanistic students was more of an intuitive type of learner.

The next section will explained the final study (Study 2B) that was developed to replicate and extend the results of Study 2A and to investigate whether the difference found in working memory performance between science and humanistic students was a result of working memory per se or a domain specific advantage. Additional tasks measuring verbal and visuospatial skills were included in this experiment to strengthen findings.

3.3 Study 2B

The fourth and final experiment was designed to investigate the working memory performance and learning skills of university students in different disciplines. Again, University students in science and humanistic departments were recruited and they completed a series of cognitive and intelligence tests to measure their short term memory and working memory, and two self-report questionnaires relating to study skills and learning preferences. However, in this study, four additional tasks were added to measure verbal and visuospatial abilities.

3.3.1 Method

This experiment was conducted after the approval from the Department of psychology, University of York Research Ethics Committee (Appendix 4).

Participants

A total of 108 undergraduate students participated in this study. Participants were recruited through posters and by email announcement via each department's student administrator. Recruitment was also done via the Psychology electronic registration for participant interested in the research (PEEBs). Individuals who were contacted by these methods were encouraged to forward the email request to their peers, especially those in the sciences department. Students who were from the Science Department such as Biology, Chemistry, Engineering and Physics *(n=52)* were assigned to the Science group while students from the Humanities and Literacy Department such as Literature, History, Philosophy & Economics and Sociology were assigned to the Humanistic group *(n=56)*. All of the students were recruited from one of the top university in the United Kingdom. Table 3.5 represents the demographic of all participants by groups and were matched as closely as possible for gender and age.

Table 3.5 Age and gender ratio of the groups of students (Study 2B)

	Humanistic	Science
No. of participants	56	52
Female, male	34,18	30,18
Age range	18-26	18-30
Mean age in years *(SD)*	19.8 *(1.431)*	20.1 *(2.290)*

3.3.2 Task materials

All of the participants were administered cognitive and intelligence tasks to measure their verbal and visuospatial short-term and working memory as well as other cognitive abilities. Two self-reported questionnaires were then completed that measures participants' study skills and learning preferences. All the materials used in Study 2B were the same materials used in previous experiments which have been described in chapter 2. However, additional measures were also included in this experiment to tap the verbal and visuospatial abilities. Tasks such as Spoonerisms and Proof Reading from the York Adult Assessment (Hatcher & Snowling, 2002) were administered to measure literacy and phonological skills whereas Mental Rotation Task Test (adapted by Vandenberg, 1971) and Rey Complex Figure Test (Meyers & Meyers, 1995) to measure visuospatial skills.

Below are the details of these tasks:

Proof reading

This is a task taken from the York Adult Assessment (Hatcher & Snowling, 2002). It is a proof reading task consisted of a passage with 13 errors, including errors of spelling, punctuation, grammar and word repetition. The task is to assess students' ability to identify written errors in the passage. The score was the total number of text errors that were uncorrected plus the number of correct word spellings, punctuation or grammatical markers that were marked as incorrect (erroneously).

Spoonerisms

This is another task taken from the York Adult Assessment (Hatcher & Snowling, 2002). This test is to assess students' ability to segment and manipulate phonemes, by asking them to exchange the beginning sounds of two words. The words were well known names (e.g., 'Terry Wogan' would become 'Werry Togan'). Following training and practice items, 12 test items were administered. Both speed and accuracy were recorded.

Mental Rotation Task Test (M.R.T. Test)

M. R. T. test is a paper and pencil mental rotation test adapted by Vandenberg (1971) and revised by Crawford (1979). The test consisted of several two-dimensional drawings of 10 cubes attached to each other and rotated in different directions. The only difference between the original cube series and the new selections is that they are presented at different angles. Two out of the four cube selections can be matched to the original and two cannot be matched. The test had two parts, with three minutes to complete each of the two parts. A stopwatch was used to time each section and the break between each section. Each part had two pages with five sets of the cube selections on each page. Making the total number of series selections being 10 for each section. A score sheet was used to collect data. Scoring was based on correct and incorrect answers, for every wrong answer 0.5 point will be subtracted from the total number of correct answers. The subtraction is to correct the 50% chance of being correct in guesswork.

Rey Complex Figure Test (RCFT)

The RCFT is also a paper and pencil task to assess individual's visuospatial abilities, memory, attention, and working memory (executive functions) (Meyers & Meyers, 1995). In Rey complex figure test, participants have to complete a copy and an immediate recall trial. In the copy trial, participant will be required to copy a figure (given on a piece of stimulus card) on a sheet of paper. While for the immediate recall trial, participant is required to draw the figure again but from memory. Immediate recall task is administered 3 minutes after the copy trial is completed. Scoring will be based on both accuracy and placement with a maximum point of 36 (18 unit points).

3.3.3 Procedure

Testing took place in a quiet room where participants were provided with a brief description of the study and then asked to sign a consent form prior starting the tasks. Each participant will fill in basic demographic information which included name (optional), age, gender, current year of study, A-level grades, the department and the degree that they took in university. The cognitive assessments, tasks and questionnaires were administered individually to all of the participants. The AWMA was presented first followed by WAIS-III. The questionnaires were then administered last. The testing lasted between 60-90 minutes depending on how the participants performed in the tasks. Following the completion of the testing session, participants were debriefed, and questions pertaining to the study were addressed. Participants were then given either payment or course credits for their participation in the study.

3.3.4 Results

The data collected from all of the participants were gathered and analysed using the Statistical Package for Social Sciences version 17 (SPSS 17). Multivariate Analysis of Variance (MANOVA) and correlation studies were completed and assumptions were met. Below are the details of the statistical result for each component that this study measures.

Working memory

A MANOVA was conducted in order to examine whether there is any significant difference between science and non-science groups of students in their working memory performance. Table 3.6 shows the descriptive statistics of each working memory tasks based on the composite score for each of the groups. Wilks' Lambda was at $F(4,103)=3.597$, $p<0.01$, partial $\eta^2=0.12$, indicating an overall group difference in the working memory measures. Further univariate analyses indicated 2 significant differences between the groups. Science students performed significantly lower on both verbal short term memory $F(1,106)=8.079$, $p<0.01$, partial $\eta^2=0.07$ and verbal working memory tasks $F(1,106)=7.604$, $p<0.01$, partial $\eta^2=0.07$.

Table 3.6 Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 2B)

	Non Science		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
AWMA					
Digit recall	104.64	14.54	101.36	15.32	1.298
Nonword recall	113.87	13.06	104.02	12.50	15.967**
Verbal STM	109.25	12.04	102.69	11.91	8.079**
Listening recall	105.51	14.99	98.69	13.23	6.239*
Backward digit recall	101.59	14.45	95.52	14.28	4.813*
Verbal WM	103.55	12.97	97.10	11.16	7.604**
Dot matrix	97.77	15.56	100.77	12.63	1.199
Mazes memory	96.28	12.18	99.75	12.30	2.170
Visuospatial STM	97.02	11.34	100.26	10.40	2.376
Odd one out	102.28	14.50	103.06	12.61	0.087
Spatial recall	101.52	14.08	99.21	14.81	0.693
Visuospatial WM	101.90	12.48	101.13	10.89	0.116

Note: AWMA = Automated Working Memory Assessment (Alloway, 2007); STM = short-term memory; WM = working memory.*p<0.05, **p<0.01

General cognitive abilities (Wechsler Adult Intelligence Scale**)**

The data on WAIS-III was also analysed using MANOVA to investigate whether there is any differences between the disciplines of studies in terms of general cognitive abilities. Table 3.7 provides means and standard deviations as well as univariate analyses for general intelligence tasks (WAIS-III) scores for both groups. No significant group difference was found between science and humanistic students on performing the verbal and non-verbal tasks $F(4,103) = 0.511$, *ns* (*p=0.728;* partial η^2=0.02).

Table 3.7 Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 2B)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
WAIS-III					
Processing speed (Digit-symbol coding)	11.55	3.01	11.58	2.73	0.002
Perceptual organisation (Block design)	12.75	2.96	13.21	2.35	0.796
Working memory (Mental arithmetic)	12.14	2.26	12.00	2.08	0.116
Verbal comprehension (Information)	13.68	1.87	13.31	1.91	1.036

Note: WAIS-III = *Wechsler Adult Intelligence Scale –III* , *p<0.05, **p<0.01

Domain specific performance

To investigate whether the differences found between the disciplines in working memory performance was due to working memory differences per se or domain specific advantage, a MANOVA was conducted for both data on the additional verbal and visuospatial measures.

For verbal domain, a significant group difference was found between science and humanistic students in these verbal measures with $F(3,104) = 4.152$, $p<0.01$, partial $\eta^2=0.11$. Further univariate analyses indicated 2 significant differences between the groups in proof reading error scores $F(1,106) = 7.006$, $p<0.01$, partial $\eta^2=0.06$, and accuracy scores in spoonerism tasks $F(1,106) = 7.086$, $p<0.01$, partial $\eta^2=0.06$. Table 3.8 shows the descriptive statistics for the verbal and visuospatial measures for both groups. Science students were found to make significantly more proof reading errors compared to humanistic students while performing significantly more poorly on the spoonerism task. However, for the visuospatial domain, no significant group difference was found in the visuospatial tasks, $F(4,103) = 1.385$, *ns* ($p=0.244$; partial $\eta^2=0.05$).

Table 3.8 Descriptive Statistic for additional verbal and visuospatial tasks as a Function of Group (Study 2B)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
Verbal tasks					
Proof read error scores	2.04	1.56	2.83	1.54	7.006**
Spoonerism accuracy scores	23.50	0.81	22.63	2.28	7.086**
Spoonerism response time	1.15	0.56	1.29	0.59	1.699
Visuospatial tasks					
MRT- trial 1	10.33	4.97	10.65	4.75	0.119
MRT- trial 2	9.21	4.95	10.83	4.70	3.037 p=0.084
Rey – Copy	34.87	1.50	35.19	1.12	1.615
Rey – Immediate	24.55	4.53	24.89	6.15	0.108

*p<0.05, **p<0.01

Learning and study skills performance

Although in previous experiment (Study 2A) there was no significant difference between groups in learning and study skills, a MANOVA analysis was done for the LASSI data to add strength to previous findings. As predicted, no significant group difference was found in the learning and study skills performance between students in different disciplines, $F(10,97) = 1.341$, *ns* (*p=0.220*; partial η^2=0.12). Table 3.9 shows descriptive statistics for LASSI subscales for both groups of students.

Table 3.9 Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by Group

Measure	Humanistic *M*	Humanistic *SD*	Science *M*	Science *SD*	*F*
LASSI					
Anxiety	28.30	5.71	26.61	8.18	1.565
Attitude	31.66	3.82	31.86	4.20	0.070
Concentration	26.36	5.17	24.98	7.24	1.306
Info. Processing	28.98	3.78	28.29	4.74	0.712
Motivation	31.61	4.28	31.29	4.47	0.143
Self-Testing	23.75	4.26	21.88	6.09	3.444
Selecting Main Ideas	28.77	5.07	28.94	5.13	0.032
Study Aids	23.89	4.12	23.79	5.18	0.014
Time Management	24.32	5.49	24.19	7.29	0.011
Test Taking	31.00	3.70	29.13	5.01	4.889*

Note: LASSI = Learning and Study Skills Inventory (Weinstein et. al, 2002); *p<0.05, **p<0.01

Learning preferences/tendency

A MANOVA was also conducted on the ILS converted scores. Based on the analyses, Wilks' Lambda was significant at $F(4,103)=3.570$, $p<0.01$, partial $\eta^2=0.12$, indicating an overall group difference in learning tendencies. Further univariate analyses indicated 2 significant differences between the groups in active reflective learning preferences $F(1,106) = 4.832$, $p<0.05$, partial $\eta^2=0.04$ and sensing intuitive learning preferences $F(1,106) = 8.231$, $p<0.01$, partial $\eta^2=0.07$. Table 3.10 provides means and standard deviations as well as univariate analyses for learning styles scores for both groups.

Table 3.10 Descriptive Statistics for the Learning preference (ILS) as a Function of Group (Study 2B)

	Humanistic		Science		
Measure	*M*	*SD*	*M*	*SD*	*F*
ILS					
Active/Reflective	-1.82	3.88	-0.12	4.97	4.832*
Sensing/Intuitive	-0.86	4.97	1.88	4.95	8.231**
Visual/Verbal	1.54	4.71	2.54	5.71	0.998
Sequential/Global	0.07	4.31	1.58	4.29	3.301 p=0.072

Relationship between working memory performance and other measures

A correlation analysis was conducted on all the measures in this study to investigate if any relationships between these variables exist especially between working memory variables and learning and study skills by utilising the Pearson's Correlation Coefficients (*r*). Bivariate correlations between verbal and visuospatial short-term and working memory measures with learning and study skills and learning tendency scores obtained in university students are provided in Table 3.11. Based on this table, there was a positive relationship between student's performance in verbal short-term memory tasks, and their performance on mental arithmetic and information tasks in WAIS-III tests, $r = .25$, $p < 0.01$, $r = .18$, $p < 0.05$ respectively. Verbal short-term memory performance was also positively correlated with spoonerism accuracy, $r = .22$, $p<0.05$ while negatively correlated with proof reading errors at $r = -.383$, $p<0.0001$.

In terms of the relationships between verbal short-term memory and learning styles and study skills, significant relationships was found between verbal short-term memory tasks with anxiety management, selecting main ideas techniques, and test taking strategies at $r = .17$, $r = .18$, $p<0.05$, $r = .25$, $p<0.01$ respectively. Verbal short-term memory performance was also found to be correlated with sensing learning preferences, $r = -.32$, $p<0.0001$. The same pattern of relationships was found between verbal working memory performance and other measures mentioned above. Verbal working memory was associated positively with mental arithmetic task, r = .27, and information task, r = .30 in WAIS-III; as well as significant correlation found with proof reading errors, r = -.29, spoonerisms accuracy, r = .35, anxiety management, r = .18, information processing, r = .24, test taking strategies, r = .18 and sensing, -.32 and sequential learning preferences, r = -.24 (all $p<0.05$).

On the other hand, visuospatial short-term memory and visuospatial working memory performance was found to significantly correlated with block design scores, r = .51, r = .38, mental rotation, r = .38, r = .46 and Rey memory scores, r = .30, r = .28 (all $p<0.01$) respectively. There was also positive relationship between visuospatial short-term memory performance with information task, r = .26, and visual learning preferences, r = .20, $p<0.05$. While visuospatial working memory scores was significantly related with mental arithmetic task, r = .38, sensing learning tendency, r = -.20, motivation scores, r = -.23, and time management strategies scores, r = -.22 in LASSI (all $p<0.05$). Another table further contains the correlations between other cognitive ability measures with study skills (Table 3.12).

Table 3.11 Correlations between working memory and other cognitive ability measures and study skills for all participants using Pearson's correlation coefficient (Study 2B)

	AWMA			
Variable	A1	A2	A3	A4
Verbal STM (A1)	1			
Verbal WM (A2)	**0.58**	1		
Visuospatial STM (A3)	0.01	**0.21**	1	
Visuospatial WM (A4)	**0.24**	**0.50**	**0.51**	1
Digit-symbol coding	0.03	-0.02	0.14	0.14
Block design	0.00	0.10	**0.51**	**0.38**
Mental Arithmetic	**0.25**	**0.27**	0.15	**0.38**
Information	0.18	**0.30**	**0.25**	0.16
Proof read error	**-0.38**	**-0.29**	0.05	-0.07
Spoonerism accuracy	**0.22**	**0.35**	-0.12	0.11
MRT	0.04	0.14	**0.38**	**0.46**
Rey Copy	0.02	0.07	0.09	0.15
Rey Memory	-0.07	-0.04	**0.30**	**0.28**
Anxiety	0.17	0.18	0.03	0.06
Attitude	0.05	0.13	-0.00	-0.02
Concentration	0.02	-0.00	-0.12	-0.15
Information Processing	0.10	**0.24**	0.06	0.11
Motivation	-0.14	-0.12	-0.05	**-0.23**
Self-Testing	0.06	0.06	-0.15	-0.05
Selecting Main Ideas	0.18	0.09	0.04	-0.09
Study Aids	0.07	0.04	-0.01	-0.06
Time Management	-0.03	-0.08	-0.13	**-0.22**
Test Taking	**0.25**	0.18	0.005	-0.06

Note: All coefficients >.20 are significant at the .05 level and all coefficients >.30 are significant at the .01 level.

Table 3.12 Correlations between study skills and other cognitive ability measures for all participants using Pearson's correlation coefficient (Study 2B)

	LASSI									
Variable	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Anxiety (L1)	1									
Attitude (L2)	**0.20**	1								
Concentration (L3)	**0.40**	**0.35**	1							
Information Processing (L4)	0.11	-0.08	0.12	1						
Motivation (L5)	0.15	**0.43**	**0.59**	0.06	1					
Self-Testing (L6)	0.10	0.14	**0.31**	**0.40**	**0.34**	1				
Selecting Main Ideas (L7)	**0.44**	**0.36**	**0.46**	0.16	**0.29**	0.15	1			
Study Aids (L8)	0.15	0.14	**0.33**	0.14	**0.32**	**0.24**	**0.26**	1		
Time Management (L9)	**0.20**	**0.23**	**0.69**	0.01	**0.57**	**0.32**	**0.23**	**0.35**	1	
Test Taking (L10)	**0.47**	**0.40**	**0.58**	0.09	**0.40**	**0.22**	**0.60**	**0.25**	**0.35**	1
Digit-symbol coding	-0.09	0.07	-0.06	-0.15	-0.04	-0.06	0.07	-0.03	-0.02	-0.01
Block design	-0.04	0.01	**-0.20**	0.01	-0.11	-0.11	-0.01	-0.04	**-0.22**	0.00
Mental Arithmetic	0.14	0.01	-0.07	0.17	-0.14	-0.08	0.04	-0.13	**-0.23**	0.04
Information	**0.23**	0.01	-0.16	0.12	-0.13	-0.12	0.17	-0.04	**-0.36**	0.06
Proof read error	-0.15	-0.03	-0.08	0.02	0.08	0.00	-0.12	0.02	0.04	**-0.26**
Spoonerism accuracy	0.06	-0.00	-0.08	0.11	0.03	0.05	-0.04	0.10	0.00	0.03
MRT	0.08	-0.11	-0.03	**0.23**	-0.10	0.08	0.00	0.01	-0.09	-0.09
Rey Copy	-0.09	-0.03	0.06	-0.03	-0.06	**-0.23**	-0.02	0.04	-0.15	0.02
Rey Memory	0.10	0.06	-0.03	-0.11	-0.10	-0.12	0.02	-0.09	-0.19	-0.04

Note: All coefficients >.20 are significant at the .05 level and all coefficients >.30 are significant at the .01 level.

3.4 Discussion

The aim of the present study was to examine working memory profiles as well as learning strategies and study skills of non-dyslexic university students in science and humanistic disciplines. Students in the non-science group significantly outperformed those in the science group on both verbal short term and verbal working memory tasks. The present findings indicated that students in science discipline display weakness in their verbal component of working memory compared to the humanistic students. At the moment, there is no known studies investigating working memory profile of non-dyslexic students and comparing them in terms of disciplines. However, a study comparing art and non-art students has found different profile between the two groups in their phonological skills suggesting that there is probably different working memory profile for different disciplines (Wolff & Lundberg, 2002).

While learning and study strategies appear not to differ according to disciplines, science students were found to be leaning towards sensing learning preference (facts and real world) while the humanistic students were more inclined on thinking of abstract materials (theories, concepts). An interesting observation as well in the findings is that although the learning and study styles profile of students in both groups are similar, other studies in learning styles of college students have also shown almost similar learning profiles of normal students suggesting that this learning profile might be typical for the average postsecondary students with no learning difficulties (Kirby et al., 2008; Proctor et al., 2006).

The science group was also found to score lower in the mental arithmetic tasks compared to the humanistic students in the WAIS test tapping on working memory. Although there is no significant difference in intelligence between both groups based on the WAIS-III tests, students in the science department whom is more likely to deal with numbers and figures and the fact that they underperformed said something about their working memory profile. Some would argue that individuals with weakness in verbal working and short-term memory might therefore select spatial occupations or majors in order to avoid fields which require extensive reading such as History, Philosophy, English, and so on. However, there might be another reason other than avoidance to escape literacy demands but more towards acceptance or awareness of such limitations and strength (in this case visuospatial component of working memory). Hence, individuals who have extensive activity in some domain are most likely individuals who have sought out such activity. When individuals seek out an activity and engaged in it extensively, they may do so because they have a tendency to perform well in that area. Thus, suggest that the experiences and therefore major discipline individuals choose are at least partly due to innate learning and memory profiles.

Could students with dyslexia be predisposed to science disciplines such as physics, chemistry, biology or even health science? What does their working profile shows? Do science students have advantage in their visual working memory compared to students in other disciplines that is so useful in science? A few studies of spatial professions have demonstrated a disproportionate incidence of dyslexia in such groups (Winner et al., 2001).

Dyslexic students were also found to be positively associated with superior visual spatial ability compared to students without dyslexia; however the empirical evidence is inconsistent. Von Karolyi, Winner, Gray and Sherman (2003) showed that individuals with dyslexia have visual-spatial talent to process information globally rather than part by part which illustrate that they are more inclined to conceptualized information in a visual spatial rather than a verbal, way. Brunswick, Martin and Marzano (2010) investigated dyslexic visual-spatial advantage by comparing dyslexic and non-dyslexic adults on tests of everyday visual-spatial ability and although they did not find difference between groups on visual-spatial tasks performance, they did observed significant sex x group interactions. Their study suggested that the visual-spatial advantage in dyslexia may be confined to men (Brunswick et al., 2010). One reason for inconsistency in finding genuine visual-spatial superiority in dyslexia may be due to the findings reported based on differing methodologies, heterogeneous and small samples (Brunswick, Martin and Marzano, 2010).

The discovery of strength and weakness associated with disciplines may eventually lead to more effective educational strategies and help guide individuals to professions in which they can excel (Von Károlyi et al., 2003).

3.5 Summary

Interesting findings from Study 2A and Study 2B showed that there are differences between Science and Non Science students in their working memory performance based on the working memory test battery (in Study 2A) and with the extra verbal and visuospatial tasks applied in Study 2B. The result prompt us to explore the data further (data collected in Study 2B) by using Structural Equation Modelling (SEM) which is a statistical methodology to study or test the working memory theories in particular. The next chapter (Chapter 4) explains and discuss the result of this analysis. Further discussion on the correlation and relationship between variables investigated in Study 2 will be presented in Chapter 5.

CHAPTER FOUR

CONFIRMATORY FACTOR ANALYSIS

4.1 Introduction

This chapter starts with an introduction to the Structural Equation Modelling (SEM) and the way it addresses key issues relating to Study 2B. The result and analysis of several path models based on working memory theories will be presented followed by the discussion of the findings at the end of this chapter.

4.2 Structural Equation Modelling (SEM)

In Chapter 1, theories of working memory were discussed, starting with Atkinson & Shiffrin (1968) unitary modal model, the multi-component working memory model of Baddeley & Hitch (1974), Baddeley (1986, 2000) to discussion of various alternative models of working memory including Cowan's embedded process theory and Barrouillet, Bernardin & Camos (2004) time-based sharing model. The aim of conducting the CFA to explore the structure of the verbal and visuospatial short-term memory and working memory in young adult learners based on the working memory theories and empirical findings from previous research. CFA was chosen as a way to assess the fit between the hypotheses models of short-term memory and working memory with the data gathered in Study 2B.

Structural Equation Modelling (SEM) is a powerful statistical technique that is use to investigate the complex relationships either between the one or more independent variables and one or more dependent variables (Weiner, 2013 cited in Ullman & Bentler, 2013), or examined the relationships between unobserved (latent) variables or observed (measured) variables (Ullman & Bentler, 2013). It can examine the relationships between latent variables. Most researchers used SEM to specify confirmatory factor analysis models, complex path diagrams, and regression models (Hox & Bechger, 1998). One of the purposes of using SEM is to come up with confirmatory factor analysis (CFA) models that are imposed on the data (Mueller & Hancock, 2008). The path models are derived from theoretical findings and empirical studies and SEM is a good methodology to investigate which of the theory-derived models provide a good fit to the observed data. SEM also allows explicit testing between these competing models (Hair, Black, Babin, Anderson, Tatham, 2006).

The SEM method using the confirmatory factor analysis (CFA) tests the adequacy of the hypothesised model in corresponding to the observed pattern of data, with each path model representing the relationship between the observed variables and latent constructs and between constructs.

Below are the specific path models/diagrams that will be addressed and tested using this statistical technique:

1. The distinction between verbal and visuospatial domain is a 2-factor model (verbal and visuospatial as latent factors) that best fit the data of working memory performance of these young learners (Shah & Miyake, 1996).

2. The domain-specific view of short-term memory and working memory representing as 2 latent factors is a 2-factor model that fit the observed data well.

3. A 3-factor model encompasses of a single domain general working memory factor and two separate storage factors for verbal and visuospatial measures based on Baddeley working memory model (2000) (Baddeley & Hitch, 1974; Baddeley, 2000; Engle et. al, 1999) that best fit the data.

   This model also represents a domain general view of working memory capacity based on current theoretical model of working memory (Cowan et. al, 2005; Friedman & Miyake, 2000; Miyake et al., 2001; Bayliss et al., 2003; see also Bayliss, Jarrold, Baddeley, Gunn, & Leigh, 2005).

4. A 4-factor model consists of four domain specific constructs including verbal short-term memory (factor 1), visuospatial short-term memory (factor 2), verbal working memory (factor 3), and visuospatial working memory (factor 4) will provide best fit of the data (Kane et al., 2004).

The degree of domain generality or domain specificity of working memory capacity has been tested and explored in some previous studies using this approach. Alloway, Gathercole, & Pickering (2006) did CFAs to examine the structure of verbal and visuospatial short-term and working memory in 236 children between 4-11 years old. They findings support a domain general view of working memory capacity with domain specific storages for verbal and visuospatial resources. Another study investigating the structure of working memory performance in adults using SEM & CFA approach was conducted by Kane and colleagues in 2004. A total of 250 adult participants from various university and community centre completed tasks measuring their verbal and visuospatial short-term and working memory in addition to tests of verbal and spatial reasoning and general fluid intelligence. The best-fitting model based on their analyses was the four-factor model with distinct verbal and visuospatial short-term and working memory constructs. Their results also indicated that the working memory tasks reflected more of a domain general factor whereas the short-term memory tasks were more domain specific (Kane et al., 2004).

4.3 Method

A total of 108 students participated in Study 2B where 52 learners were assigned in the Science group and 56 students in the Non Science group. Successions of tasks were performed by the participants in order to capture the cognitive processes underlying working memory. The data was collected, analysed and presented in Chapter 3 (Study 2B) including the means, standard deviation and correlation between variables. The participants' data and the proposed models were tested using AMOS 16 (Arbuckle, 2007) which is one of the SEM software packages. The proposed models were tested on the full data set for all participants. The raw scores for each of the observed (measured) variables were used as input. The data were screened for multivariate outliers.

Each theory-derived models will be represented by a path diagram consisting of the latent factors (unobserved/unmeasured variables) represented by a circle or ellipse and the observed factors (measured variables) represented by squares or rectangles. Each observed variable has an error path associated to it (residual error term; err). Relationship between these variables is indicated by lines with one or two-headed arrow. One headed arrow represents a hypothesised direct relationship between two variables where the headed arrow points to the dependent variable while a two-headed arrow implies covariance or correlations without implying direction of effect (Ullman & Bentler, 2013).

In each of the path models tested, paths between the latent factors will be left to co-vary (represented by the double-headed arrow) with the assumption that the latent factors are correlated and no specific direction of causality. The proposed path models are also known as measurement models since the paths only show the relation between the measured variables with the latent variables. For each factor or latent variables, the factor loading for one of the observed variables is fixed to one to estimate the factor variances (Hox & Bechger, 1998). All hypothesised models showing path coefficients between each of the latent constructs as well as between measured variables are available in Appendix 3.

In order to evaluate the path models, a succession of chi-square statistic and chi-square difference tests were conducted and reported following the presentation of each proposed path models. The chi-square statistic is a commonly used index of goodness of fit, which compare degree of similarity between the estimate population variance/covariance (matrix computed from the path model) to the sample variance/covariance (raw data). A smaller and non-significant chi-square value indicates better fit; however chi-square statistic is sensitive towards sample size. A very large sample size might result in significant statistical test even though the model actually describes the data well. On the other hand, with small sample size, there is a possibility of the model be accepted when it fits rather badly (Hox & Berger, 1998). There are several fit indices that can be used to evaluate best-fitting models that are less sensitive towards sample size. Models with well-defined constructs (Kline, 1998), reliable measured variables, and having strong parameter estimates may require less sample data (Ullman, 2007), even allowing testing of path models with as few as 60 participants/data (Yuan & Bentler, 1999).

Goodness-of-Fit indices that are recommended include comparative fit index (CFI; Bentler, 1990; Hoyle & Patner, 1995), the bollen fit index (IFI; Bollen, 1989), and the normed fit index (NFI; Bentler & Bonet, 1980) which is one example of incremental fit indices. If the values of these fit indices equal to or higher than .90, the model demonstrates a good fit. McDonald & Ho (2002) and Kline (2005) also recommend using the root mean square error of approximation (RMSEA) with value of .08 or lower as acceptable model and a value below .05 which shows a good fit. After the best fit model was identified, the proposed models were also examined for the different group of learners.

4.4 Results and Analysis

The first path model, Model 1, is a CFA model with 2 latent factors and 8 observed variables as shown in Figure 4.1. Model 1 was derived from empirical studies that indicate separate groups of domain specific resources between the verbal and visuospatial memory constructs (Miyake & Shah, 1996; Daneman & Tardiff, 1987) and were assumed to cause the variation and co-variation between the eight observed variables. The verbal factor was linked to four verbal memory measures while the visuospatial factor was associated to four visuospatial memory measures. This 2-factor model does not provide a good fit to the observed data where the chi-square value is highly significant and the fit indices are less than .90 as shown in Table 4.1.

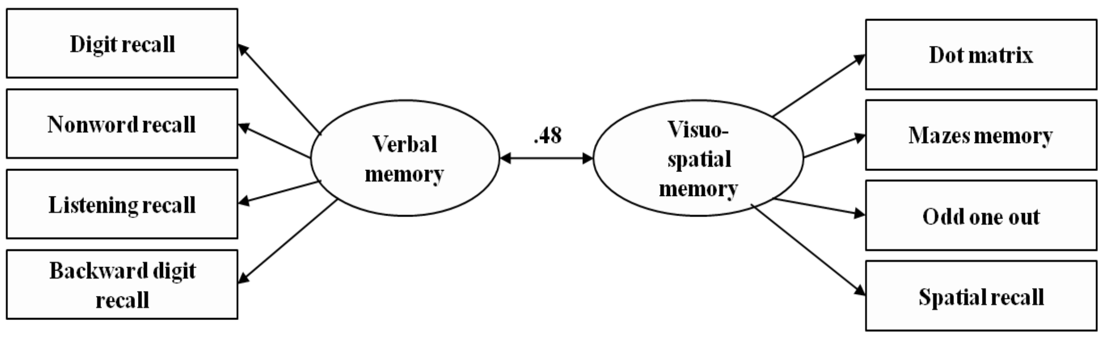


Figure 4.1. A simple path diagram for 2-factor model based on the distinction between verbal and visuospatial memory measures.

The next path model, Model 2, is a CFA model with 2 latent factors and 8 observed (measured) variables as shown in Figure 4.2. Model 2 was derived from the domain specific view of the short-term and working memory measures (Swanson & Luxenberg, 2009). The short-term memory factor was linked to four short-term memory measures while the working memory factor was associated to four working memory measures. Based on the chi-square statistic, this 2-factor model does not provide a satisfactory fit to the observed data where the chi-square value ($p<.001$) is highly significant, all fit indices are less than .90, and the RMSEA value exceeds .08 as shown in Table 4.1.

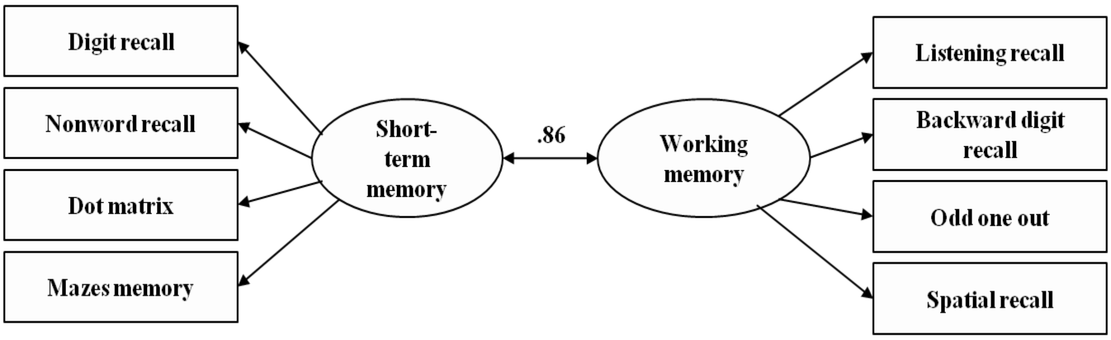


Figure 4.2. A simple path diagram for a 2-factor model corresponds to short-term memory and working memory.

The third path model, Model 3a, is a CFA model with 3 latent factors and 8 observed (measured) variables as shown in Figure 4.3. Model 3a is a three-factor model centred on a single domain general working memory factor (including both the verbal and visuospatial storage and processing tasks) and two distinct storage factors for verbal short-term memory measures and visuospatial short-term memory measures. The Model 3a is consistent with Baddeley & Hitch tripartite working memory model as explained in Chapter 1 (Figure 1.2), as well as that of Engle et. al (1999). Referring to the goodness-of-fit statistic, Model 3a provided a better fit to the data than either Model 1 or Model 2, with a lower chi-square value (although still highly significant, $p<0.001$). Nonetheless all fit indices were below .90, and the RMSEA = .121, still showing poor fit to data.

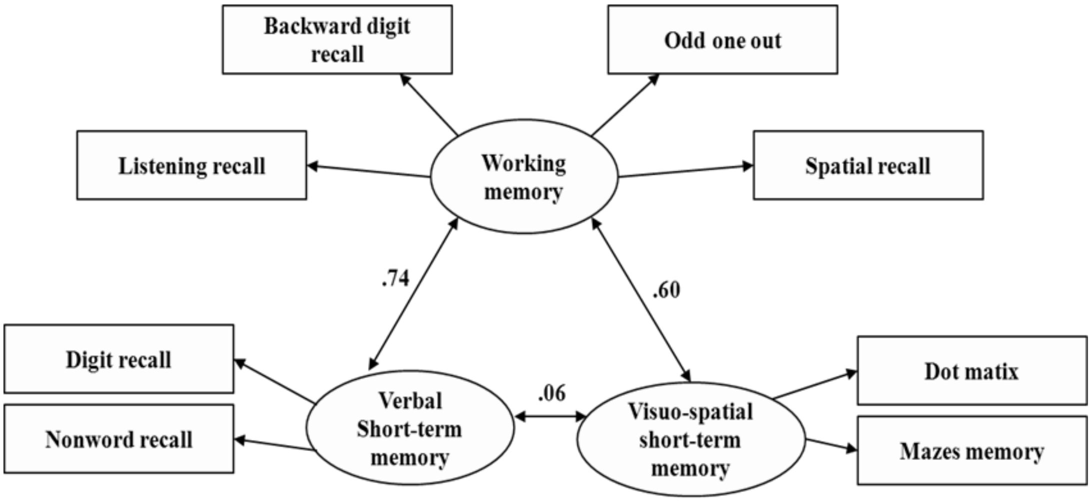


Figure 4.3. Path diagram (Model 3a) for a 3-factor model with one domain general working memory factor and 2 distinct storage factors for verbal and visuospatial short-term memory correspond to Baddeley & Hitch (1974) working memory model.

Figure 4.3 represents Model 3a showing no path lines from the four working memory measures to the corresponding domain storage for either the verbal and visuospatial factors. Since the working memory tasks measure together storage and processing of information in either verbal or visuospatial domain, there should be path lines drawn from the verbal and visuospatial short-term memory factors to their corresponding working memory measured variables. Therefore another model, Model 3b, was constructed and examined but with the appropriate path lines from the domain specific short-term memory factors to the appropriate working memory measures represented in Figure 4.4. Model 3b provide a very good fit of the data with a chi-square value which is in non-significant ($p > 0.05$) and lower than the other models as indicated in Table 4.1. All fit indices also shows values higher than .90 demonstrating good fit with a lower RMSEA<.05 as well. A chi-square difference test compares the fit of this model with previous theory-derived models. Table 4.2 shows the result of the chi-square difference between Model 3b and Models 3a ($\Delta\chi^2 = 30.82$, df = 4, $p<.001$), Model 3b and Model 2 ($\Delta\chi^2 = 60.47$, df = 6, $p<.001$), and Model 3b and Model 1 ($\Delta\chi^2 = 24.1$, df = 6, $p<.001$) providing support that Model 3b represent the best account of these observed data.

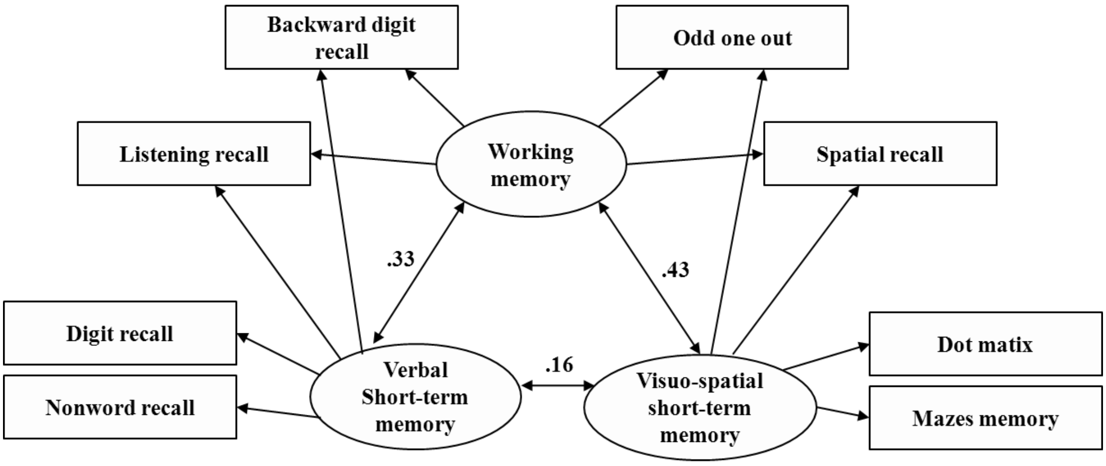


Figure 4.4. Path diagram (Model 3b) representing a 3-factor model with a single domain general working memory factor and 2 separable storage factors for verbal and visuospatial short-term memory correspond to Baddeley & Hitch (1974) WM model.

The final path model, Model 4, is a CFA model with 4 latent factors and 8 observed (measured) variables as shown in Figure 4.5. Model 4 is a four-factor model representing the four domain specific constructs; verbal short-term memory (Factor 1), visuospatial short-term memory (Factor 2), verbal working memory (Factor 3) and visuospatial working memory (Factor 4). Model 4 is a model derived from the current theoretical model of working memory based on adult data (e.g Cowan et. al., 2002). While Model 4 seems to provide a good fit to the data as model 3b (refer to Table 4.1), the complexity of the path diagram resulted in multicollinearity problems rendering solution not admissible.

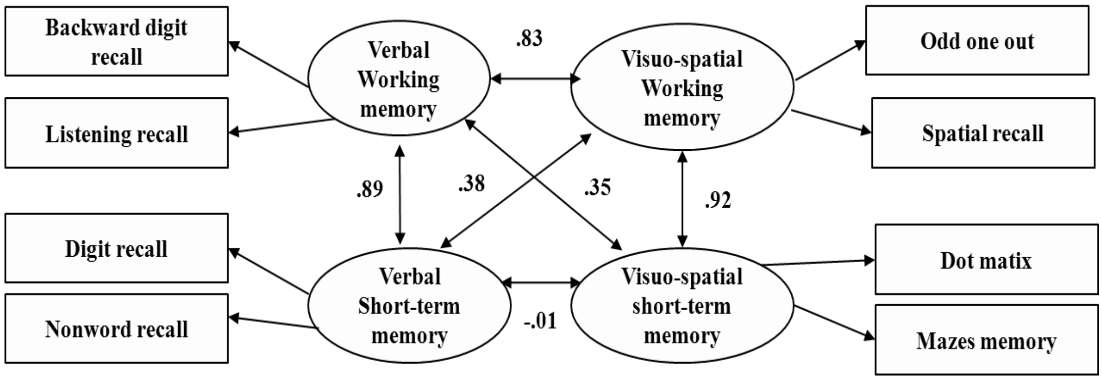


Figure 4.5. Model 4 is a path model with 4 latent factors with separate verbal and visuospatial working memory and separate short-term memory constructs each co-varies between each other.

Table 4.1 Goodness-of-Fit Statistics for the Different Measurement Models for all the Participants as well as for each Science and Non Science Group

Model	Group	χ^2	*df*	*p*	CFI	IFI	NFI	RMSEA
1	All	37.00	19	.008	.91	.91	.83	.094
	Science	25.28	19	.152	.91	.92	.74	.080
	Non Science	18.32	19	.501	1.0	1.0	.87	.000
2	All	73.37	19	<.001	.72	.73	.67	.164
	Science	39.96	19	.003	.69	.73	.58	.147
	Non Science	40.43	19	.003	.80	.82	.70	.143
3a	All	43.72	17	<.001	.86	.87	.80	.121
	Science	26.52	17	.065	.86	.88	.72	.105
	Non Science	26.01	17	.074	.92	.93	.81	.098
3b	All	12.90	13	.45	1.0	1.0	.94	.000
	Science	7.38	13	.89	1.0	1.0	.95	.000
	Non Science	11.14	14	.68	1.0	1.0	.88	.000
4	All	14.02	14	.45	1.0	1.0	.94	.004
	Science	14.14	14	.44	.99	.99	.85	.014
	Non Science	9.02	14	.83	1.0	1.0	.93	.000

Table 4.2 Model Comparison Statistics for Each Group Band Between Models 3b and Model1, and Model 2, and Model 3a

	Model 1			Model 2			Model 3a		
Group	$\Delta\chi^2$	*df*	*p*	$\Delta\chi^2$	*df*	*P*	$\Delta\chi^2$	*df*	*p*
All	24.1	6	<.001	60.47	6	<.001	30.82	4	<.001
Science	12.38	6	ns	27.06	6	<.001	13.62	4	<.05
Non Science	5.42	5	ns	27.53	5	<.001	13.11	3	<.05

Note: ns = not significant. $\Delta\chi^2 = \chi^2$ difference.

4.5 Discussion

The purpose of using Structure Equation Modelling (SEM) in analysing the full data set from Study 2B is to investigate the structure of verbal and visuospatial short term memory and working memory based on various theories of working memory.

In order to answer the questions above, 108 undergraduate students from one university performed a number of tasks that correspond to either verbal or visuospatial short-term memory or working memory. In Study 2B (Chapter 3), the participants also performed additional verbal and visuospatial tasks to examine domain differences. Next, confirmatory factor analysis and structural equation modelling were used to test the hypothesis with regards to the working memory and short-term memory constructs as well as verbal and visuospatial constructs.

The first path diagram (Model 1) was proposed representing a 2 factor model testing whether the memory performance of these young adults can be viewed better in terms of distinction between verbal and visuospatial memory measures. Miyake and Shah (1996) debated that working memory capacity can be explained by a separate and distinct verbal and visuospatial storage. They proposed a domain specific view of working memory capacity where findings from their study reported that verbal tasks such as reading span predicted Scholastic Aptitude Test (SAT) performance better than a spatial task while conversely a spatial span predicted visual-spatial tests better than reading span. Other research show similar findings with reading span (verbal task) predict only verbal performance while rotation span (spatial task) predicts only spatial performance (Friedman & Miyake, 2000).

Results on the CFA and chi-square fit indices indicate that Model 1 does not provide a good fit to the data. However, the findings don't mean that the model which differentiate between verbal and visual-spatial measures have to be rejected, it just means Model 1 is a poor model to explain the association observed in the actual data. Although the correlation between the verbal and visuospatial variables in Model 1 was significant (0.48), it was not as high as the correlation between the short-term memory and working memory constructs (0.86) as depicted in the second path diagram (Model 2). Model 2 was proposed to examine whether the distinction between short-term memory and working memory variables was a good structure in explaining the performance of young learners. Based on the results of chi-square value and the other fit indices the second path also provides a poor fit to the data.

According to Miyake and Shah (1996) study, if our sample population comes from a homogeneous group, it will be much easier to detect domain specific contribution and mechanism in performance where difference in verbal and visuospatial abilities might be more obvious. However, although the participants for my current study are homogeneous in nature (for example, high ability undergraduate population gathered from one university), and results from Study 2B indicate differences between groups of Science and Non Science students on working memory performance (where the Non Science students performed better than the Science group in both verbal short-term and working memory tasks), the proposed model based on distinction between verbal and visuospatial constructs is not the correct model to explain the data. Therefore another possible model to examine the pattern of performance is the domain general view of working memory capacity.

Model 3 and Model 4 was proposed to address the issue of domain general versus domain specific of working memory capacity based on several key theoretical models of working memory especially the Baddeley & Hitch (1974) multi-component model of working memory. Both Model 3a and Model 3b represent the relationship between one domain general working memory factor with two separate and distinct domain storages for verbal and visuospatial factors. The only difference between these two path diagrams is that Model 3b has additional paths linking the verbal short-term memory factor to the appropriate working memory measures such as the backward digit recall and listening recall variables and additional paths linking the visuospatial short-term factor to working memory construct such as odd one out and spatial recall variables. The additional links resulted in Model 3b to have a non-significant chi-square value ($p<0.05$) with a much lower RMSEA value indicating that this model provides best fit (χ^2 (13, N=108) =12.90, p=0.45; CFI=1.0; NFI=.94; RMSEA= .00) and the best account of the actual data compared to other models (based on chi-square difference tests shown in Table 4.2). The good fit shows that the variance-co variance matrix is well represented by Model 3b that also indicates the structural model to represent a good fit to the measurement model.

According to Muller and Hancock (2007), a hypothesised model with acceptable fit may be interpreted as one plausible explanation for the associations observed in the data. The working memory performance of young adults in the present study can best be explained by a structure with a single domain general working memory component responsible for the processing of information from the two domain specific storage of both verbal and visuospatial nature corresponds to Baddeley & Hitch (1974) and Baddeley (1986, 2000) working memory model. Although Model 3a represent the same theoretical structure of working memory model as in Model 3b, the absence of paths between the verbal and visuospatial short-term memory storage with the corresponding working memory measures resulting in the model to show a poor fit to the data.

The last hypothesised path diagram represents Model 4 which is a 4-factor model with separate domain specific for short-term memory and working memory constructs as well as for verbal and visuospatial latent constructs. While CFA results on Model 4 also shows a non-significant chi square (χ^2 (14, N=108)=14.02, p=0.45; CFI=1.0; NFI=.94; RMSEA=0.004) indicating that Model 4 also shows a good fit to the data, there is a problem of multicollinearity. The results might be attributed to the model (the measurement model was not well defined), for example, two latent factors might be better modelled as only one factor and the high correlations among the latent constructs (p=0.75 to 0.95) also might contribute to multicollinearity (Grewal, Cote, & Baumgarthner, 2004). With multicollinearity, although a good solution is obtained, it can lead to inaccurate parameter estimates and increase probability of Type II error especially with small sample size (n=108).

Thus based on the CFA and SEM results of all proposed models and model comparison tests presented in Table 4.2 (chi-square difference test) between Model 1, Model 2, Model 3a with Model 3b, it can be conclude that Model 3b provide the best account on the relationships between and among the working memory and short-term memory measures. The results are also consistent with previous latent- variable investigation on the structure of working memory capacity in children and adults (Alloway, Gathercole & Pickering, 2006; Kane et al., 2004). It provides evidence of the underlying cognitive feature mechanisms responsible for the participants' pattern of performance.

4.6 Summary

This chapter starts with a brief explanation of Structural Equation Modelling (SEM) and the Confirmatory Factor Analyses that was chosen to test hypothesised models (estimated variance) against measurement model (actual variance). Four proposed models were tested and only one showed a good fit to the observed data and the model correspond to the domain general view of working memory capacity. In conclusion, the findings from the present adult study indicate that the theoretical structure of working memory capacity is consistent with the view that there is a domain general component for processing information and domain specific components for storage of verbal and visuospatial inputs.

CHAPTER FIVE

CONCLUSION

5.1 Introduction

The study was set out to explore the working memory profiles, study skills, and learning preferences of dyslexic and non-dyslexic individuals in higher learning institutions. The thesis also sought to identify and understand students' weaknesses and strengths in their cognitive profiles, their preferences in learning style, as well as their study skills that they adopted in an independent learning environment. Data from the research was analysed to evaluate the current working memory models using structured equation modelling techniques. With deep understanding of the relationship between cognitive profiles, learning skills, and study preferences, appropriate support and study intervention could be given to young adult learners with dyslexia towards achieving their optimum potentials.

The first section of this chapter outlines the summary of the whole research, followed by discussion of the main research findings reported in Chapter 2, Chapter 3, and Chapter 4 with regards to previous literature. Implications for practice and future research would also be outlined. This chapter ends with a conclusion of the study.

5.2 Summary of the Research

Cognitive and educational research over the past two decades (Gathercole & Alloway, 2008; Swanson, Cochran, & Ewers, 1990) have established the significant relationship between working memory and learning especially among children. Working memory is an active part of the brain that juggles current information while processing and manipulating it using previously stored knowledge from long-term memory in order to execute or complete a task. Therefore, the capacity and effective functions of working memory determine the extent of learning that occurs in individuals.

Various studies in working memory are also associated with deficits in the subcomponents of working memory that could be related to a wide range of learning difficulties (Isaki, Spaulding, & Plate, 2008; Jeffries & Everatt, 2004; Pickering, 2006; Roodenrys, 2006).

The working memory difference between dyslexic and non-dyslexic individuals has been identified in previous research among children (Alloway & Gathercole, 2006; Archibald & Gathercole, 2006; Pickering, 2006; Pickering & Gathercole, 2004; Scheepers, 2009) as well as among adults (McLaughlin et al., 1994; Smith-Spark, Fisk, Fawcett, & Nicolson, 2003; Winner *et al.*, 2001). Studies on dyslexic adults indicated that the difference between dyslexic and non-dyslexic individuals lies in the verbal component of working memory with weakness shown in the central executive and phonological storage component. Meanwhile, the comparative strength existed in their visual spatial domain (Jeffries & Everatt, 2003). Findings from studies conducted by Smith-Spark and Fisk, however, showed that the impairments of working memory in dyslexic adults appeared not only in verbal or phonological component, but displayed weakness in the visuospatial component as well (Smith-Spark & Fisk, 2007). The researchers argued that the central executive, in addition to the storage problem in verbal and visuospatial modalities, contributed to the working memory deficits found among the dyslexics. The evidence for deficits in the visuospatial domain of the dyslexics remains questionable.

With the increasing number of students with learning disabilities applying for further education, it is vital that the current study could contribute to the existing knowledge of working memory profiles among dyslexic adults in higher education. However, the research on working memory capacity of young adults with dyslexia in higher education is still limited (Jeffries & Everatt, 2003; Smith-Spark & Fisk, 2007). The persistence difficulties faced by dyslexic adult learners affect their study skills when pursuing to a higher level of education. Skills like reading, writing, time management, attention, concentration, managing anxiety, and self-confidence are among the study skills required in independent learning. A study conducted by Hatcher, Snowling, & Griffiths (2002) on the cognitive skills of dyslexic students in higher education found that the common problems faced by dyslexic learners, especially in reading and writing, still exist due to their learning difficulties.

Studies on dyslexic adults mainly focus on the relationship between reading ability and study skills. Dyslexic students who were found to have a lower reading ability as compared to the normal group were also discovered to have difficulties in identifying important points from passages and in selecting appropriate testing strategies (Kirby *et al.*, 2008). Thus, the present study also seeks to address how working memory directly influences learning outcomes and whether study skills might have anything to do with it.

In the current investigation, two main studies were conducted to evaluate the working memory performance, study skills, as well as learning tendencies of dyslexic adult learners and typical learners in college and university in York, United Kingdom. Overall, similar results based on previous literature were found in the first study (Study 1A and Study 1B) involving dyslexic and non-dyslexic adult students. Differences in working memory performance were significant between dyslexic and non-dyslexic groups, showing lower scores in the verbal and visuospatial short-term and working memory tasks in the dyslexic group. Differences in learning and study skills were also identified with the dyslexic group reported to have used less effective time management strategies, test taking strategies, selecting main ideas techniques, as well as issues with concentration and anxiety when approaching academic tasks. The relationship between the working memory components and study skills were found, suggesting a pattern of association which would be discussed further in the next section.

The second study involved normal university students with no learning disabilities, comparing the non-dyslexic learners in terms of their academic disciplines (science versus humanities) in their working memory performance, study skills, and learning styles. The main reason for conducting Study 2 was to further investigate whether the difference that was found between dyslexic and non-dyslexic learners in their working memory performance in Study 1 was attributed to the difference in learning disabilities, or a general difference due to dissimilarity in learners' cognitive profiles in the way individuals receive, store, and process information. Interestingly, comparable finding was replicated in Study 2 where the difference of working memory between the science and humanistic groups was found, showing the advantage of verbal working memory in the humanistic group.

Further exploration with a bigger sample size as well as additional verbal and visuospatial tasks strengthened the results, as displayed in Study 2B. Participants in the science group performed significantly lower in the verbal tasks compared to the humanistic group, and no difference was found between the groups in the visuospatial tasks performance.

Meanwhile, students' study skills were compared between the science and humanistic learners. No significant group difference was found between the two disciplines. However, based on the Index of Learning Styles scores, the science group learning tendencies were more on the active and sensing types of learners. Correlation analyses conducted in Study 2 showed that there were significant relationships between components of working memory with other cognitive measures but no significant relationship between study skills. A confirmatory factor analysis was also conducted with the data from Study 2 to test hypothesised models of working memory. The findings showed that the best fit models of actual data were the Baddeley & Hitch (1974) and Baddeley (1986, 2000) working memory models with domain-general component and domain-specific component for verbal and visuospatial information.

Overall, the findings from Study 1 and Study 2 suggest that working memory performance could be a factor that differentiates between dyslexic and non-dyslexic learners of different disciplines. The next section provides in-depth discussion on the empirical findings and contributions to enhance the understanding of working memory, study skills, and learning preferences between dyslexic and typical adult learners.

5.3 Main Findings and Reflections

Overall, my thesis contributes to the following knowledge and claims.

Establishing different working memory profiles between dyslexic and non-dyslexic adult learners

The working memory profile of dyslexic adult learners is different from the working memory profile of non-dyslexic adult learners.

The finding of the thesis clearly established that the working memory profile of the dyslexic adult learners differs from their non-dyslexic peers. The working memory profile of dyslexic adults in higher learning institutions showed weaker phonological or verbal working memory component as compared to their visuospatial working memory component. The verbal working memory deficits found in intellectual dyslexic adult learners were found to be persistent throughout adulthood. Therefore, the present findings shown in Chapter 2 provided further evidence that the working memory problems associated with dyslexia still persist in these young adult learners.

There is an abundance research on dyslexia among children and relatively little research on dyslexia among learning adults. The main aim of Study 1 was to compare the working memory components, study skills, and learning preferences of dyslexic and non-dyslexic adults in higher learning institutions. Study 1A was conducted with the selection of college students between 16 to 22 years old as participants. Study 1B was the extension of Study 1A with university students as participants. The dyslexic group comprised of students with a Psychological Assessment Report, indicating dyslexia as one of their learning problems, or college students who were identified by their Special Education Needs officer or advisor and invited to participate in the study. A total of 26 individuals with dyslexia and learning problems was assessed along with a group of 32 non-dyslexic adults. The size of dyslexic group was constrained by the limited number of diagnosed students willing to participate in the study. On the other hand, a non-dyslexic comparison group comprised of students reporting no learning disabilities were selected to carefully match the dyslexic group in terms of their age and gender. In order to reduce the chance of making Type I error, it was necessary to ensure that the dyslexic and the comparison groups were matched on as many variables as possible so that the results obtained were due to the group differences and not because of other confounding variables that might lead to the chance of making Type II error instead.

To investigate the working memory profiles, the study adopted instruments that could automatically measure participant's performance in working memory tasks. A computerised measurement developed by Alloway in 2007, the Automated Working Memory Assessment (AWMA), was used to assess the verbal and visuospatial short-term and working memory of the students. A general cognitive measure was also conducted to evaluate the general intelligence of the groups by adopting two verbal and two nonverbal tasks from the Wechsler Adult Intelligence Scale III (WAIS-III) tests.

Initial findings of the working memory measures from Study 1A showed that there was a significant difference between the dyslexic and the comparison group in working memory performance. Students in the dyslexic group performed significantly poor on verbal short-term memory and verbal working memory tasks compared to students in the comparison group. The mean of standardised scores of verbal short-term and working memory were one standard deviation below the average mean – 83.87 and 83.83 respectively, reflecting deficits in these areas. The dyslexic group was also found to achieve a significantly lower score in tasks related to visuospatial short-term memory than students with no learning disability. A significant difference was also discovered between the groups in mazes memory that measures visuospatial storage capacity, where the non-dyslexic group outperformed the dyslexic group in that task. This is consistent with other studies that found visuospatial deficits in dyslexic individuals (Palmer, 2000; Pablano *et al.*, 2000).

Findings from Study 1B, however, found no significant effect in group with learning difficulties across the working memory tasks. Even though no significant group difference in working memory performance was found between the dyslexic and the comparison groups in Study 1B, a fairly large mean difference exists between the groups in the verbal working memory composite scores. The non-significant results related to the differences between the groups might be attributed to Type II error because of the small sample size. Data from the university dyslexic sample indicated that the students performed well in the verbal working memory tasks with scores above 85. A longitudinal study would be appropriate to analyse the differences in the working memory performance found among dyslexic students in college and university. Possible explanations include changes in cognitive development, increasing self-awareness or metacognitive strategies, as well as having found ways to overcome weaknesses and highlighting strengths to be successful at the university level.

Studies conducted on children and adults with learning disabilities demonstrate that cognitive deficiency is an indicator of learning problems faced by these individuals which include deficits in phonological processing, attention, short-term memory, and working memory (Masoura, 2006; Nicholas & Fawcett, 1995; Rack, Snowling & Olson, 1992; Snowling, 1981; Swanson & Berninger, 1996). Impairment in working memory has been implicated with many learning difficulties and developmental disorders, including specific reading difficulties (Pickering, 2006) and dyslexia (Jeffries & Everatt, 2004). These findings concur with previous literature on dyslexic performance in verbal tasks (Gathercole & Pickering, 2000; Pickering & Gathercole, 2001). On the other hand, the finding of this study is expected to suggest current theories and definition of dyslexia. It could also be considered as the extension of previous findings discovered in McLoughlin (2002), Pickering (2006), and Jeffries & Everett (2004) who were researching on dyslexic children and adults in memory tasks. Similar deficits have also been found in younger children (Alloway, Gathercole, Adams, & Willis, 2005; Gathercole, Alloway, Willis, & Adams, 2006; Pickering, 2006) and adults (Jefferies & Everatt, 2003; Wilson & Lesaux, 2001).

Investigating further into each component of short-term and working memory constructs, the differences between the groups were significant in the digit recall, listening recall, backwards digit recall, and mazes memory subtasks in Study 1A while a significant difference was only found in the verbal working memory for both listening recall and backwards digit recall in Study 1B. Consistent with previous research on the verbal working memory performance of dyslexic individuals (Ackerman & Dykman, 1993; Gathercole, Willis, Emslie, & Baddeley, 1992), significant impairments were found on the digit recall, listening recall, and backwards digit recall (Fostick, Bar-El, & Ram-Tsur, 2012; Sela, Izzetoglu, Izzetoglu & Onaral, 2012). Hence, the nature of the working memory deficits suggested problems with storage and central executive for the verbal stimulus and not just limited to weakness in the phonological storage. Therefore, findings from Study 1 provide additional evidence to support the working memory deficit theory as one of the causes or characteristics of dyslexia at the cognitive level as discussed in Chapter 1 (Section 1.4.1).

Establishing differences in working memory profiles, but not general intelligence or IQ

Differences between learning difficulty groups was found only in the working memory performance and not the general intelligence or IQ tasks. Findings on the performance of both groups from Study 1A on verbal and nonverbal measures via the WAIS-III tasks did not show any differences between the groups in all the four WAIS tasks. WAIS tasks were chosen to assess individual intellectual abilities. The dyslexic and non-dyslexic individuals were found to be on a par in their performance. This finding supported part of the definition or characteristics of dyslexic individuals which is showing an average or above average intelligence (IQ) but facing with difficulties in reading, spelling and writing. It has sometimes been noted as a hidden disability (British Dyslexia Association, 2011).

However, results on WAIS-III tasks from Study 1B involving university students showed a significant difference between the groups. The reported partial eta^2 was .41 meaning that the effect of group differences in the MANOVA accounted for 41% of the group-difference plus associated error variance (Tabachnick & Fidell, 2001). The univariate follow-up ANOVAs showed the significant and interesting mean difference was found in the verbal comprehension or general knowledge tasks in WAIS-III. The dyslexic group was found to perform better than the comparison group in this task. This finding shows the fact that the dyslexic group was not simply weaker in all respects, and indeed perform equally well if not better in other cognitive tasks. One interesting possibility raised by the finding is that in order to be sufficiently successful in academic learning to reach tertiary education, some areas of compensatory skills are needed in individuals with dyslexic problems. For university participants, their learning preferences as assessed by Index of learning styles (Felder & Silverman, 1988) were equivalent.

The importance of working memory and IQ in determining individual capabilities was debated among researchers where working memory measures were argued to reflect an individual's true learning potential whereas IQ measures knowledge or abilities that an individual already has (Alloway, 2009). The results of the cognitive tasks in Study 1 concur that there are differences between dyslexic and non-dyslexic learners in their working memory capacities but not in the general intelligence performance. Other research has established that poor verbal working memory but not general intelligence that have a unique relationship with both reading and mathematical achievements (Gathercole *et al.,* 2006; Seigel, 1988). Thus, from the findings, the dyslexic learner has the potential to improve their ability to learn especially when one is aware of the strength and weakness of their working memory component.

Establishing differences in the study skills of dyslexic adult learners

Meanwhile, it seems that the deficits that dyslexic students have in their verbal short-term and verbal working memory did not deter them from continuing their education successfully. The second objective of Study 1 was to investigate whether dyslexic students apply any study skills or use any different learning styles to compensate their limitations in their working memory especially the verbal component to maximise their learning capabilities. Self-reported questionnaires from Learning and Study Skills Inventory (LASSI-2) created by Weinstein *et al.* (2002) and Index of Learning Styles (ILS) developed by Felder and Silverman (1988) were adopted to explore participants' study skills and learning tendencies.

Results from the current thesis are also consistent with previous empirical studies investigating college students' study skills with and without learning disabilities. Other studies showed students with dyslexia caused problems in a wide range of academic related skills, including taking notes, organizing essays, and expressing their ideas in writing assignments (Mortimore & Crozier, 2006). Kirby *et al.* (2008) compared self-reported learning strategies and study approaches of post-secondary (university and colleges) students with and without dyslexia, as well as examined the relationship of those characteristics with their reading ability. Dyslexic students were found to use more study aids and time management strategies while using less selecting main ideas and test taking strategies as compared to non-dyslexic students.

Results from the LASSI questionnaire in Study 1A and Study 1B indicated a significant difference in terms of study skills between the dyslexic group and the non-dyslexic group. However, in Study 1A, the univariate analysis only showed one significant difference between the groups on the anxiety scale. Students in the dyslexic group scored lower in this measure which indicated high anxiety level. Students with high anxiety levels were shown to reflect negative beliefs, thoughts, and emotions on their academic performances. (Carroll & Iles, 2006; Johnson & Gronlund, 2009). They felt worried about their performances in tests or assignments that diverted their attention away from the tasks. Research on students with learning disabilities suggested that anxiety performance could be one of the important variables in determining the outcomes of the academic study (Kovach & Wilgosh, 1999). Several studies have also shown that exam anxiety is greater for students with learning disabilities than those without learning disabilities, resulting in the decrease of academic performance (Swanson & Howell, 1996). Swanson and Howell (1996) further argued that anxiety, fear, or being worried all the time about studying or performing in academic would divert students' attention away from academic tasks and bring them closer to irrational fears.

Although findings from Study 1A replicated previous research and showed differences between the dyslexic and the comparison groups in their reported use of study skills, we did not find any differences between the groups in other study skills except anxiety control. However, results from Study 1B managed to replicate findings from other studies that assessed study skills of post-secondary students with learning disabilities via LASSI. The difference between dyslexic and non-dyslexic group was significant, especially in the anxiety scale, concentration, motivation, time management strategies, as well as selecting main ideas and test taking strategies (Kirby *et al.*, 2008; Kovach & Wilgosh, 1999; Proctor *et al.*, 2006). Dyslexic students have been associated with behavioural characteristics related to anxiety management, organisation, and planning (McLoughlin, 2002). Based on the present study, the individuals seem to report similar characteristics on their learning and study skills. One interesting possibility is that the problems in learning and study skills among the dyslexic students might be a direct consequence of their poor working memory skills. Poor working memory might cause difficulties in reading and organising complex and lengthy information, leading to less use of certain study strategies. Results of correlation analysis from Study 1 demonstrate a positive relationship between these two strategies with verbal working memory. Students who performed well in their verbal working memory tasks were reported to use more effective selecting main ideas techniques and test taking strategies.

Meanwhile, students with difficulties in reading and identifying main points were reported to use less selecting main ideas or test taking strategies, which was also what the dyslexic students indicated in the questionnaires. Studies on disability showed that post-secondary students with dyslexia were reported to have a distinctive learning strategy and study profile to that of other students (Kirby *et al.*, 2008; Kovach & Wilson, 1999; Proctor *et al.*, 2006). Thus, one of the aims of this thesis is to increase the understanding of cognitive limitations and compensatory strategies of students with learning difficulties to provide appropriate instructions in learning strategies to maximise academic success. For the purpose of evaluating students' learning and study strategies, the Learning and Study Strategies Inventory (LASSI) was adopted by researchers. The instrument has been proven reliable and applicable to different levels of education including schools, colleges, and universities across various countries with different cultural backgrounds (Albaili 1997; De Zoysa, Chandrakumara, & Rudkin, 2014; Yip, 2007; 2009; 2013).

Another significant group difference was also found in terms of the learning styles and tendencies between the dyslexic group and the comparison group. However, the significant difference was the result of one dimension of learning styles, referring to an active or reflective type of learner. Students with no learning disabilities were found to have learned more on being an active type of learners, a case which was not applicable to the students with dyslexia. Active learners prefer doing, working, and solving things in a group or a team, however, reflective learners prefer to work at their own pace and think carefully when completing a particular task and prefer to work alone (Weinstein *et al.*, 2002). The findings add to the evidence of the behavioural pattern found in dyslexic students where they prefer to work alone rather than in a group (Gathercole *et al.*, 2008; Gathercole *et al.*, 2006; McLoughlin, 2002). Overall, although results reported in this study both in working memory along with learning and study skills' profiles of dyslexic students replicate findings from previous research, it adds strength to the limited working memory research done among older students with learning difficulties.

Establishing different working memory profiles between science and humanistic learners

The working memory profile of non-dyslexic science learners is different from the working memory profiles of non-dyslexic humanistic learners. Study 2 examined the working memory performance of non-dyslexic science and humanistic students in higher education. Initial findings from Study 2A showed that there exists a significant group difference between the non-dyslexic learners in terms of their disciplines when performing the working memory tasks. Participants from the science group scored a significantly lower score in the verbal short-term and verbal working memory assessments (98.91 and 97.67 respectively) compared to participants from the humanities group (110.50 and 105.05 respectively). Investigating further into the individual subtasks, significant low scores were found in the digit recall, non-word recall and backward digit recall tasks of the science group. Meanwhile, in the visuospatial short-term memory and visuospatial working memory tasks, there were no significant differences between the scores among the two groups. Data from the extension study (Study 2B) also reflected similar differences between groups in working memory performance, especially in the non-word recall and backward digit recall; therefore strengthen the findings in Study 2A. Based on these results, it could be argued that the non-dyslexic students from the science group showed weakness in their verbal short-term and verbal working memory compared to their non-science peers.

Extra verbal and visuospatial tasks were included in Study 2B to investigate whether there is any domain-specific difference between the science and non-science group. Another crucial point of measuring processing in both verbal and visuospatial domains is that it provides a means of assessing whether the working memory differences are simply because of general domain-specific skills. The general domain-specific skills might be or might not be specific to the working memory. With regards to the findings, significant differences were found in both proofread and spoonerism tasks. The science group was found to perform poorly in both tasks. Thus, the findings support a general domain-specific skill that is specific to working memory processes in the verbal domain. In this case, there is a clear evidence that the science students showed different working memory profiles from the humanistic group where their weaknesses are more to the verbal working memory skills.

The strength of the current findings is that it shows that the working memory profile of science students is different from other group of students and that the difference lies in the verbal component of working memory. No known studies have investigated the difference of working memory between non-dyslexic students in comparison to terms of disciplines. Links between the phonological loop, visuospatial sketch pad, and the central executive with science as a field of specialisation are yet to be explored. Previous studies have found positive relationship between working memory capacity and science attainment (Chen & Whitehead, 2009; Hussein & St Clair-Thompson, 2006; Overton & Bugler, 2012). In Chen & Whitehead's study, students with higher working memory capacities were found to understand physics better. However, their study used Pacual-Leone's Figural Intersection Test, a mental capacity task to measure working memory capacity which was different from the working memory assessment used in the current thesis. It was based on the multi-component of working memory model (Baddeley, 2000; Baddeley & Hitch, 1974). Findings from this study could increase educators' awareness of the cognitive limitations or weaknesses that the science students might encounter. Overloading the students' verbal working memory might have detrimental effects on science learning. Design of appropriate teaching and learning materials, which in this case focuses more on visual study aids, could be tailored to support students working memory capacity and capability.

In Study 2, the general cognitive tasks showed a significant group difference in Study 2A but no group difference was found in Study 2B. The initial data with 60 students indicated that participants from the science group scored lower in the mental arithmetic task compared to the comparison group. The mental arithmetic task from WAIS-III was chosen to measure subjects' working memory capacity and part of WAIS-III verbal IQ component. Participants had to hold the numbers while manipulating the mathematical formula to find the correct answers in their heads. However, when the data were analysed again based on 108 samples, no difference between the groups on the WAIS-III performance was found. The results of the intelligence test were therefore inconclusive.

Establishing the premise that there is no difference in the study skills of typical adult learners

Study 1 shows that the study skills of the dyslexic group were different compared to those without dyslexia. The students in the dyslexic group were found to differ in their anxiety scale, concentration, time management, selecting main ideas, and test taking techniques. However, in Study 2, when comparing between the science and humanistic groups in all LASSI scales, no significant difference was found between them. Interpreting the LASSI scales' scores individually; the areas that the students focused most are the anxiety scale, information processing skill, selecting main ideas, and test taking strategies. The participants in both groups scored above the 50th percentile level for the mentioned 4 study skills, indicating that these are the skills that they were reported to have used the most in academic setting. On the other hand, the other LASSI score such as attitude and interest, concentration and attention to academic tasks, motivation and willingness to work hard, self-testing which is reviewing or preparing before class, use of supporting materials, and use of time management techniques, were below the 50 percent percentile, indicating that these study skills were not the students' priority.

In terms of learning tendencies or styles, results from Study 2A show no significant difference between the groups. However, in Study 2B when the data and sample were extended, a significant difference between the groups was found. It shows that there is a difference between science and non-science students in terms of their learning styles and tendencies. Investigating further into the specific learning preferences, participants from the non-science group rated themselves to be more of a reflective type of learner while participants from the science group rated themselves to be more of a sensing type of learner. According to the Felder-Silverman model, students need to be aware of their possible strengths and possible tendencies that might lead to success or difficulties in academic setting. Although the authors caution that the learning style profile does not reflect a student's suitability or unsuitability for a particular subject, discipline, or profession (Felder, 2010), it does provide a general idea the type of learning preferences and tendencies that these groups of students tend to choose. Thus, the instructors will be able to construct teaching materials or design a learning environment that caters to most of the learning styles of the students in order to optimise learning (Felder, 2010).

Establishing the relationship between working memory component and study skills

Another research question that was highlighted in the beginning of the study is to investigate whether there is any significant relationship between the component of working memory, learning styles, and study skills variables. Positive correlations were found between verbal short-term memory and verbal working memory, as well as visuospatial short-term memory with anxiety. Meanwhile, a negative correlation was found between verbal working memory with motivation. The students who were able to perform well in any of the three memory tasks were found to report good anxiety management skills. For students who performed well in the verbal working memory tasks, they were reported to be less motivated academically. However, the findings from the correlation data should be taken cautiously because of the small sample which does not reflect the actual population. Caution is needed to be adhered when interpreting correlation as it does not always mean a change in one variable, causing the other variables to also change. The change might be attributed to a third factor.

One explanation with regards to the significant relationship that was found between cognitive profiles and study skills was proposed by Kirby *et al.* (2008). They conducted a study on dyslexic students' learning and study skills and found similar pattern of results. Their argument was that the weaknesses of learning and study skills among the dyslexic students were the result of students' poor working memory skills. With reference to Table 2.17, the correlation results from the combined data from Study 1A and Study 1B did indicate that there were positive relationships between anxiety, attitude, selecting main ideas, and test taking scales with verbal short-term memory and verbal working memory performances. The better the participants scored or performed in the verbal short-term memory or verbal working memory tasks, the higher the score given on their application of these study skills. It does fit with the fact that dyslexics do have problems with managing time and finding difficulties in reading, writing, and spelling that would contribute to less use of these study skills. However, these areas of weaknesses could be improved through educational interventions such as appropriate learning and study skills courses, professional assistance, or extra tutorials and study aids. In short, Study 1 managed to replicate findings from previous studies on children and adults with dyslexia in terms of working memory profiles and study skills.

A qualitative research via extensive interviews was conducted by Reis, McGuire, & Neu (2000) on compensation strategies adopted by students with learning disabilities who were academically successful in college. Their research found that the students were aware of their limitations and used compensation strategies to overcome them. Study strategies, cognitive and learning strategies, compensatory supports, environmental accommodations, opportunities for counselling, self-advocacy, and the development of an individual plan which include awareness of cognitive abilities and executive functions were among the compensatory strategies used by these students. These were supported and provided by the schools' learning disability programmes (Reis, McGuire, & Neu, 2000). Hence, working memory assessment was proven to be able to identify the part of working memory that is weaker and related to the unsuccessful application of study strategies, leading to the interference in academic success. These learning and study skills could then be targeted for remedial intervention with an additional training on working memory which could also help to increase learning performance.

Conclusively, although results reported in this study in working memory along with learning and study skills profiles of dyslexic students replicate findings from previous research (Gathercole & Pickering, 2000; Jeffries & Everatt, 2004; Kirby *et al.*, 2008; Pickering & Gathercole, 2001; Proctor *et al.*, 2006; Wilson & Lesaux, 2001), this study still gives additional strength to the little working memory research done among older students with learning difficulties. Another important discovery is a significant relationship was found between the component of working memory and learning and study skills. Although the sample size of the population is quite small, these encouraging findings suggest that individuals with learning difficulties need to understand and be aware of their cognitive strengths and limitations which would further identify suitable learning and study skills. These areas could be compensated for successful learning.

Establishing links between atypical (Study 1 – Dyslexia) and typical (Study 2 – Science) learners in terms of the relationship between working memory profiles and study skills

Reflecting back on the empirical evidence found in Study 1 and Study 2 with regards to working memory profiles and study skills of atypical and typical adult learners, some interesting patterns were noted. The working memory profiles of both the dyslexic group and the science group were similar, displaying a poorer performance in their verbal working memory to that of their comparison groups. The finding of this thesis shows that there is a group of learners, in this case the science major students, with similar working memory profiles – displayed weaknesses in their verbal working memory – as the dyslexic group. Nonetheless, their weakness in verbal working memory does not reflect any differences in the study skills or strategies that they adopted. Problems in identifying a smaller group of learners from those who have reading difficulties or verbal working memory difficulties such as dyslexia were brought forward by Elliot & Grigorenko (2014). Previous studies have shown that working memory deficits and phonological deficits are among the characteristics of dyslexia. However, the working memory findings in Study 1 and Study 2 reflected this issue where it would be a problem to distinguish between these two groups of learners based on their working memory profiles.

Meanwhile, the degree of weaknesses in the verbal working memory might be related to the study skills that the students used in their learning. Although the comparable findings were found in the working memory profiles of these two groups of learners, only the dyslexic group shown significant differences in six areas of study strategies namely Anxiety, Concentration or Attention, Motivation, Selecting Main Ideas, Time Management Techniques, and Test Taking Strategies compared to the non-dyslexic group. However, in Study 2, no significant group difference was found in LASSI (Learning and Study Skills Inventory). Even though the science group shows similar working memory profile as the dyslexic group, it is not reflected in the study skills used in their everyday learning, especially in anxiety management and selecting main ideas skills that were related to verbal working memory as in the dyslexic group. The verbal working memory score for the dyslexic group was one standard deviation below the average mean (m=86.50) while for the science group it was much higher (m=97.10).

A positive relationship was found between the verbal working memory and anxiety study skill. It is a study skill on how student managed their own thought processes, beliefs, and emotions which in turn affect their academic performance. A low score reflected high anxiety and the need to learn techniques for coping with anxiety and reducing worry. A positive relationship was also found between verbal working memory with Selecting Main Ideas. This study skill is the ability to select the important materials for in-depth attention, separating important from unimportant information that is not necessary to be remembered. If a student has a problem in selecting critical information, then the learning task will become more complicated by the huge amount of material that the individual is trying to acquire. A low score or a lack in this skill increases the likelihood that the student will not have enough time to understand the material well. Test taking strategy was also found to be positively correlated with verbal working memory. This study skill prepares student for the type of performance that is required and how to maximize that performance. A low score – very significant difference between dyslexic and non-dyslexic groups in Study 1, was found in anxiety, concentration or attention, selecting main ideas, and test taking strategies were found to be related with working memory. Concentration or attention was referring to the ability to focus and maintain attention on school-related activities, and able to disregard irrational or distracted thoughts or emotions.

It should also be noted that these studies were conducted separately, thus the evidences do not fully testify or support the argument. Further investigation on the relationship between working memory and academic performance with study skills as mediator – mediator variable explains the relationship between independent and dependent variables – should be the way forward. With larger data, a path diagram representing a mediation model could be analysed as discussed in Section 5.3. The analysis should be able to investigate the hypothesis whether study skills mediate the relationship between working memory and academic outcomes. In sum, even though the present data or findings show what have been previously stated, they do provide compelling evidence of the importance in understanding the relationship between working memory profiles and study skills of dyslexic and non-dyslexic learners.

5.4 Suggestions for Future Research

In Study 2, the observed data on working memory performance of non-dyslexic individuals prompted the research to investigate evidence for a multiple-component model of working memory using latent variable modelling such as structural equation modelling. An important issue addressed in this study is whether working memory in young adults is best characterised by a model representing a domain general resources with two domain specific storage resources for verbal and visuospatial information (Baddeley, 2000) or by a model that divided memory resources between verbal and visuospatial domains (Miyake & Shah, 1996).

In Chapter 4, a Confirmatory Factor Analyses was chosen to test hypothesised models of working memory (estimated variance) against measurement model (observable indicators). A total of 108 sources of data were collected and analysed using AMOS v16. Four theoretically motivated memory models were analysed and tested across all adult participants. Findings from the SEM analysis showed one 3-factor model indicating a good fit to the observed data and this model correspond to the domain general view of working memory capacity. Based on the analysis, the theoretical structure of working memory capacity is consistent with the view that there is a domain general component for processing information and domain specific components for storage of verbal and visuospatial inputs (Baddeley & Hitch, 1974; Baddeley, 2000; Engle *et al.*, 1999).

Data from Study 2 provide additional evidence and support for the multiple-component model of working memory via structural equation modelling and confirmatory factor analysis (Alloway *et al.*, 2006; Conway *et al.*, 2002; Engle et al, 1999; Gathercole *et al.*, 2004). Findings from the study also indicate that although there are differences between the working memory profiles between the science and humanistic group, in which both group go through the same domain general component for processing information and domain specific components of verbal and visuospatial inputs.

Next, another analysis that would be of interest is to investigate the hypothesis of whether study skills mediate the relationship between working memory capacity and academic performance or attainment. SEM can be used to investigate the relationship with latent factors directly, specifically the analysis that seeks to examine if working memory has a direct effect on academic performance and if there is an indirect effect via Study Skills, for example if Study Skills is a mediator. In the model depicted in Figure 5.1, the total effect of working memory on academic performance can be decomposed into the direct effect of Working Memory on Academic Performance and the indirect effect mediated via Study Skills (factor) variable. The paths between the Working Memory and Study Skills factors, between Working Memory and Academic Performance and between Study Skills and Academic Performance are represented by one-headed arrow indicating direct relationship between the variables.

The proposed three-factor latent variable mediation model represents an established relationship between working memory and learning based on various empirical research (Gathercole & Alloway, 2008; Pickering, 2006; Swanson, Cochran, & Ewers, 1990; Gathercole, Brown & Pickering, 2003; Jarvis & Gathercole, 2003; Alloway & Alloway, 2009; Gathercole, Pickering, Knight, & Stegmann, 2004; Alloway, Banner, & Smith, 2010; Riding, Grimley, Dahraei, & Banner, 2003; Kyndt, Cascallar, & Dochy, 2012). Most of the studies focused on the working memory capacity and academic achievements of typical and atypical learner in the early school years. The current thesis focused on data of adult learners who managed to continue their studies in higher education despite having learning difficulties such as dyslexia. The relationship between study skills and academic performance has also been supported by literatures (Albaili, 1997; Yip, 2007, 2009, 2012). High achieving students was found significantly better at utilising study skills such as time management, identifying important points, and managing anxiety. Academic performance can be measured by how well the learners achieve their educational goals which can be represented by their cumulative grade point average (GPA) or any indicator of overall academic performance in that institution. In previous studies, GPA was identified as a strong predictor of college students' academic performance (Feldman, 1993; Garton, Ball and Dyer, 2002).

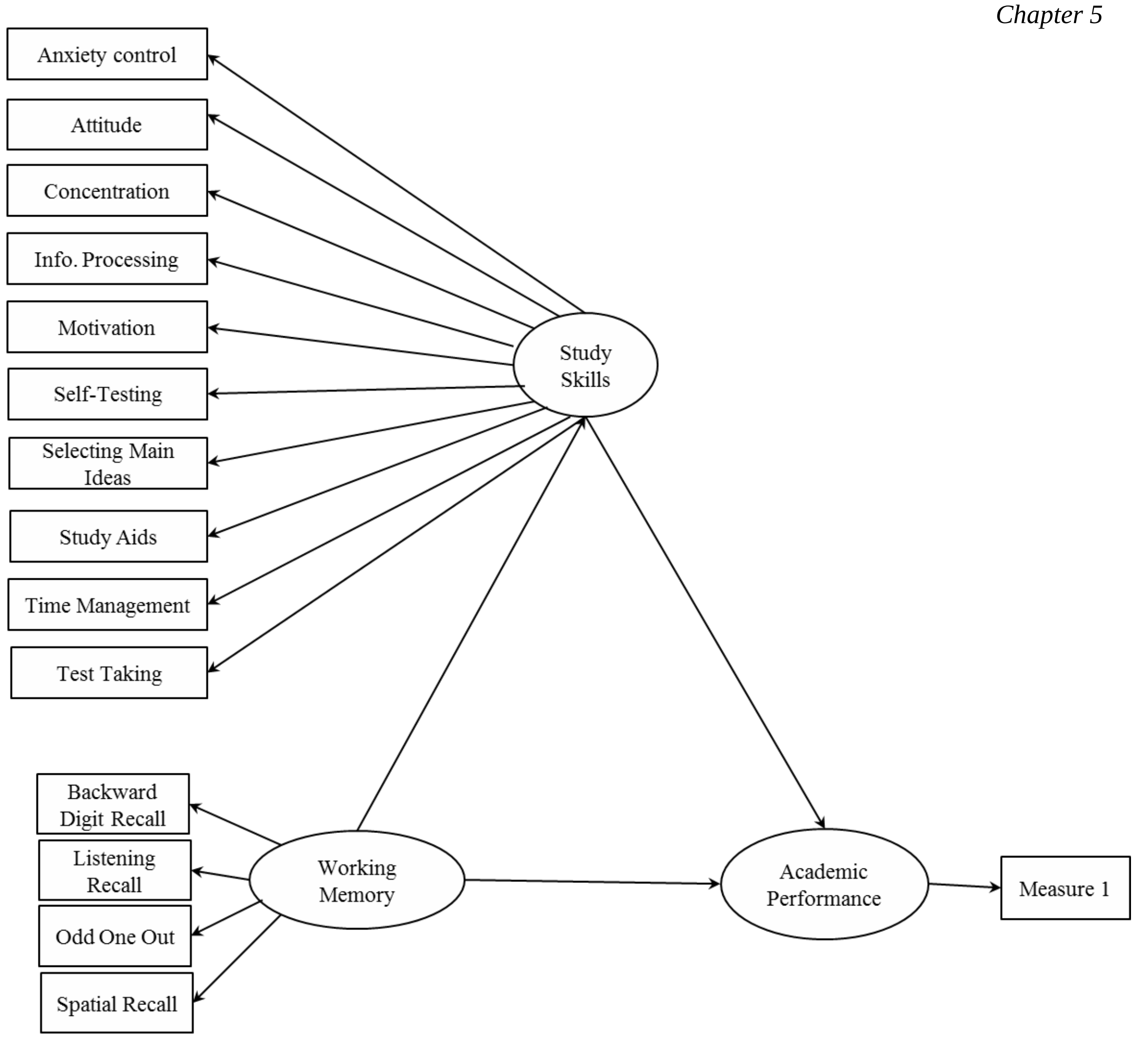


Figure 5.1. A path diagram representing the three-factor mediation model – the effect of working memory, study skills, and academic measures.

The path that shows the indirect effect of working memory towards academic performance via study skills was proposed due to the possible relationship between working memory and study skills and how these two factors directly relate to learning. The study by Kirby *et al.* (2008) on learning strategies and study approaches of post-secondary students with and without dyslexia found differences in reported study skills used between these learners. Reading ability was also found to be correlated with the significant study skills. The authors interpret the learning strategies as consequences of or compensations for the difficulties that the students with dyslexia have in word reading. With the findings from both Study 1 and Study 2, it is interesting to see whether the proposed model fits well with the actual data. The model hypothesised that working memory performance would predicted academic achievements via study skills as the mediator. It is important to analyse the size and significance of the indirect effect. For example, working memory determines one's study skills which leads to academic performance of individuals because this effect informs the underlying mechanism in the relationship between working memory and learning in groups of different learners – group differences using multi group models.

In order to claim there is a mediation effect of study skills on working memory and academic outcomes, the following conditions need to be met. The relationship between working memory, and the relationship between study skills and academic performance, need to be significant as well as a diminishing effect of working memory on academic performance when study skill factor is in the model. For each factor variables, the factor loading for one of the observable variables will be fixed to one to estimate the factor variances. A full mediation effect is achieved when all the significant variances of that relationship are accounted for by the direct effect from study skills construct to academic performance construct, with reference to Figure 5.2a. On the other hand, a partial mediation is shown if the strength of relationship between working memory and academic performance is reduced as shown in Figure 5.2b and no mediation if the effect of study skills as mediator on academic outcomes is not significant – see Figure 5.2c.

However, this analysis was not included in the thesis because due to the insufficient amount of data – small sample size – to do further latent variable analysis. To apply SEM, an adequate sample size is required and the data usually have to meet distributional assumptions. The sample size as a rule of thumb is recommended to be more than 25 times the number of parameters to be estimated, the minimum is 10 data set per estimated parameter. According to Kline (1998), the lower boundary of the total sample size should be at least 200. In general, the accuracy and stability of SEM results decline with decreasing sample size as well as an increasing number of variables. With bigger sample size, the mediation model proposed previously can be estimated and identified. Multi sample models could also be analysed between groups of different learners – the dyslexics and non-dyslexics or science and humanities. This allows the assessment between groups that could be simultaneously conducted to measure if the model fit better for one group than the other. Additional data that was not available to test the model is the academic measures (GPA).

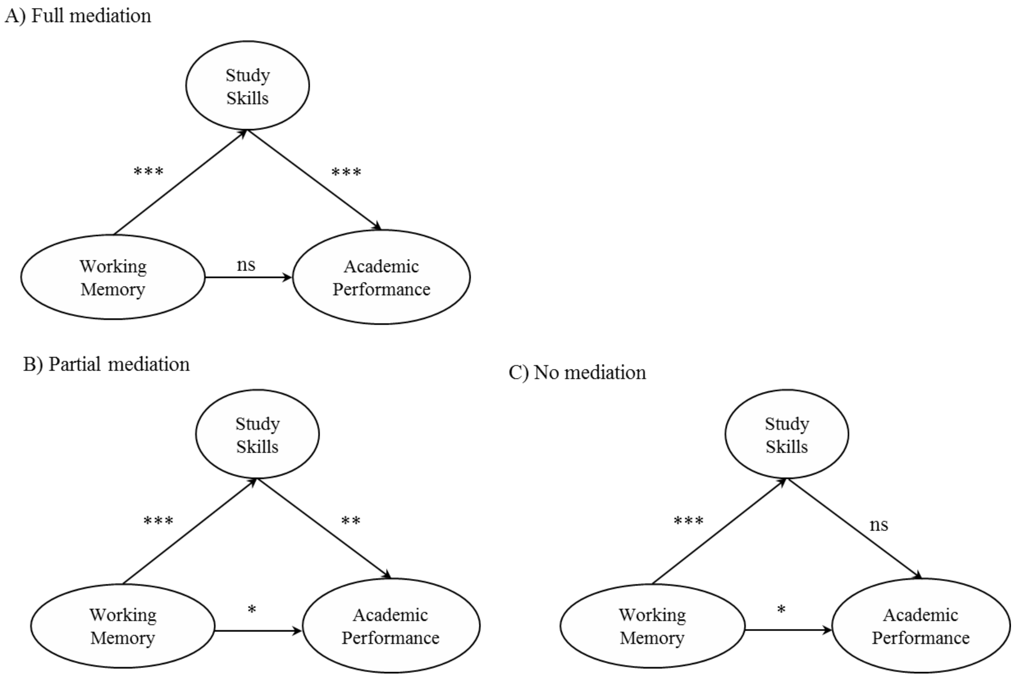


Figure 5.2. Types of mediation

If a full mediation model is established, it shows that working memory is associated with academic performance via study skills. The working memory capacity of a learner will influence their academic outcomes by how the learner utilised appropriate study skills related to learning. If a learner has weakness in their verbal working memory, it will have an impact on how they process and manipulate the verbal information that is received in the temporary storage. Information processing, selecting main ideas and concentration are the study skills that will be less utilised by this group of learners thus resulted in lower academic achievement. However, the effect size of the working memory performance will determine whether study skills will be affected. The difference between the findings from Study 1 (atypical learner) and Study 2 (typical learner) is in the study skills that the group reported using in learning situations. With a comparable difference in working memory profile between the dyslexic and science group in the verbal working memory, a significant difference in study skills was only shown in the dyslexic group compared to the science group. If the analysis of the mediation model shows, full mediation in the dyslexic group and partial or no mediation in the science group, it adds support to the patterns shown by the actual data. Gormley *et al.* (2015) did a moderation and mediation research on study skills as a mediator between ADHD status and GPA among college students (n=355). Their findings show study skills significantly mediated the relationship between ADHD status and academic attainment (GPA). However, this relationship was not significant when parents' education level was taken into account. A bigger sample size in this thesis could also contribute to additional support or evidence of study skills' differences between students with learning difficulties, although it is still relatively limited.

However, it will also be of interest to explore working memory as mediator between study skills and academic performance. These are a few examples of studies investigating working memory as a mediator; Owens, Stevenson, Norgate, & Hadwin (2008) explore working memory as mediator between trait anxiety and academic performance and Gray, Rogers, Martinussen, & Tannock (2015) who conducted a longitudinal study to determine whether working memory mediates inattentive behavior and achievement. Findings from reversing the mediation model, where working memory is placed as mediator variable, and study skills as the predictor of academic outcomes should also assist in strengthening the outcomes of the previous analysis. In this sense, study skills were used as mediator. This is an important to note since there is a correlation between working memory and study skills with no specific direction of causality.

Overall, the SEM analysis presented in Chapter 4 found a 3-factor model of working memory showing a good fit to the actual data. However, with bigger sample and additional variable in future studies, further analysis investigating relationship between working memory, study skills and academic performance can be performed.

Future research could also be built on the results of the present study by focussing on one or more of the following.

Firstly, the dyslexic study in Study 1 should be replicated with a larger number of participants from various institutions to provide a more heterogeneous sample of populations with a full range of demographic background and academic achievement. With the various definitions of dyslexia, a more systematic methodology could provide a better view of this special learning difficulties. The similarity of working memory profiles between dyslexic learners with science students would suggest that it is quite difficult to really separate between those who have specific dyslexic characteristics and those who have reading problems. Generally, a broad pool of participants with a range of cognitive abilities is useful to gain more understanding about working memory capacities.

Next, Study 2 should be replicated with various specific disciplines such as comparison in terms of working memory performance and learning and study skills between students from language department, mathematics department and physics department. Results from the study can be generalised to a more specific group of students rather than science and humanistic group. Various tools that measure students' cognitive abilities like working memory, intelligence – prior knowledge, learning and study skills, and aptitude in language – reading and writing skills, could provide useful information to investigate or develop an index of students' readiness to certain field of study. In bigger-scale study with large amount of data sets, possibilities in analysing various relationships and models using SEM could be explored.

A future research, such as a longitudinal study of postsecondary learners can help to examine whether participants awareness of their working memory profile has an impact on their use of study skills and learning outcomes and how these skills could be developed in subsequent years of learning by focusing on learning and study skills' intervention. Meanwhile, researchers could also focus on working memory intervention studies to investigate the effect of working memory training on the improvement of associated study skills to develop and increase learning performance.

5.5 Limitations of study

The thesis has offered an evaluative perspective on the contribution of working memory, study skills and learning styles of adult learners with and without difficulties. Regardless of the values of these findings have within the students in higher education context, a number of limitations were acknowledged.

The generalisation of the findings should be confined only to the participants in the institutions. Study 1 was conducted on dyslexic and non-dyslexic young adults in higher education. Hence, the conclusions derived with respect to the working memory profiles, study strategies and learning styles of the individuals, should be confined to the dyslexic students and non-dyslexic students in those college and university. The participants of the study were students from college and university in York, representing tertiary-going adults, and thus the results reported here – working memory profiles and study skills – must be interpreted with caution and cannot be generalised to other learning disabilities and other students outside of York. Other issues such as social-culture and learning environment are among factors that might contribute to differences in study skills more than working memory and should be taken into consideration.

Next, the criteria for participation in Study 1 required students to obtain a Psychological Assessment Report indicating dyslexia as their learning problem. However, for the college data, most of the students were recommended from their college support advisor as having problems with reading, writing and slow in learning which might not be attributed to being dyslexic. Because of the assignment of groups were based on being identified as having learning difficulties, either dyslexic or non-dyslexic, the two groups were already being separated due to these differences in various cognitive and psychological performance which might be a confounding variable in the study. However, the current thesis focused on investigating group differences in verbal and visuospatial working memory performance and study skills in adult dyslexics. Limited research as well as inconclusive findings with regard to working memory profiles and the learning and study skills of dyslexic learners in tertiary education motivated the research. A purposive sampling technique was used in placing participants to groups relevant to the criteria that fits the research questions.

Another limitation working with adult students from clinical populations is the issue of sample size. In Study 1A and Study 1B, the number of college and university students with dyslexia participated in the studies was 12 and 14 participants respectively. Although, this is typical in similar studies, the number is still relatively low and has consequences in the statistical analyses. In Study 2, the number of participants was also quite small, less than 200 participants. With a larger sample size, a more significant and stronger result might represent a better and stronger picture for analyses. The SEM analysis to investigate the hypothesis whether study skills mediate the relationship between working memory and academic performance can be pursued as well as other possible relationship between these two factors as discussed in Section 5.3 previously.

The matching procedure between dyslexic and non-dyslexic group in Study 1B does not take into account the discipline that the students took which might have an impact on the results of the study. Participants for the dyslexic and non-dyslexic group should be matched more specifically in as many variables as possible to avoid problems with interpretation of results. In Study 2, interesting findings showed differences between group of science and humanities learners in their working memory performances. However, when defining the inclusion criteria for the group which is field of specialisation, there might be other variables that influence the data, such as previous subjects that the students have taken during their A-levels or other entry requirements. The limitations mentioned in this thesis do not undermine the findings, but rather provide directions for the development and improvements of the method and paradigms for future research. Suggestions for future research in improving the methodology of the study will be discussed in the next section of this thesis.

5.6 Implications of the Study

The significance of this research is discussed in relation to the contribution to the literature and to practice. For the past two decades, research has established the close links between working memory skills and learning difficulties especially in children. Dyslexic children were identified to have low verbal working memory as one contributing factor on academic learning. However, there is a lack of literature investigating the working memory performance of students in higher institutions. With the increasing number of students with dyslexia entering higher education institutions, it is considered to be central to understand whether the cognitive profile of dyslexic individuals still remain similar to the cognitive profile of dyslexic children.

The findings of this research are aim to contribute to the limited literature on the links between working memory and adult dyslexic learners in higher education institutions and may have an impact on the implication for practise for the individual learner, educators and the support mechanism in college or university. The current findings are also aim to contribute to the understanding of the working memory, learning tendencies and study strategies of college and university students with learning difficulties such as dyslexia as well as typical students in higher education. According to the cognitive load theory (Paas, Renkl, & Sweller, 2003; Sweller 1988), learning happens best under conditions that are in aligned with human cognitive architecture. Investigating on the personal characteristics and abilities of students such as cognitive abilities and learning styles and how these would have an impact on their learning would be paramount. Evidence from Study 1 and Study 2, shows a possibility of the influence of working memory on the study strategies adopted by students. Understanding the effective ways in how information is received and processed for further cognitive activities is paramount. Thus, it is important to know our own cognitive weakness and strength to avoid cognitive overload and understand our own learning styles and preferences so that we can be aware of which skills that we need to develop for effective learning.

Findings from the thesis suggest that for adult students with dyslexia, weakness in the verbal short-term and verbal working memory is prevalent and may have impacted in how they use certain study skills thus influence learning. As the number of dyslexic students entering postsecondary institution increases, these students need to be aware of their cognitive strength and weaknesses so that they can concentrate and focused on compensating strategies that can help them succeed in higher education. More strategies need to be developed to minimise task demands as well as encouraging the use of memory aids.

Research investigating the relationship between working memory capacity and understanding science subjects such as physics (Chen & Whitehead, 2009) and chemistry (Hussein & Reid, 2009) found that students who have larger working memory capacity were found to perform better in various tests that demonstrate the understanding of the subject. In Study 2, science students were found to have poor performance in the verbal short-term and verbal working memory tasks. Hence, it is important for the instructors to be aware of the learner's working memory capacity so that any teaching materials or instructions can be designed to be within the working memory capacity of the learners.

5.7 Conclusions

The current study explored the working memory capacity and study skills of young adults with dyslexia as well as non-dyslexic students in different disciplines. The present research also examined the structure of working memory based on theoretical construct and actual data using the Structural Equation Modelling (SEM) and Confirmatory Factory Analyses (CFA).

Previous research in working memory and learning has shown that there is different working memory profiles associated with different learning disabilities. Individuals who were identified as having difficulty in reading or language processing such as those who have dyslexia, were found to have a weakness in their central executive and phonological loop – verbal working memory. The present research provides additional knowledge to the limited number of empirical research among the dyslexic adult population pursuing higher education in terms of working memory capacity and study skills. It also identified how these two important factors in learning relate with one another. As the understanding and awareness of working memory strength and weakness increases with respect to the dyslexic group and non-dyslexic group, the development of suitable study skills and intervention studies is imperative to support these young adults to be successful in their learning environment.

Appendix 1:

Department of Psychology

Departmental Ethics Committee

To: Kartini Abd Ghani & Sue Gathercole

From : Andrew Monk

Date: 16th March 2009

Project: Working Memory and Learning and Study Skills in Adult Learners with Learning Difficulties

Thank you for submitting your research proposal for scrutiny by the Departmental Ethics Committee. I am writing to tell you that the Committee has no objection to the proposal in principle on ethical grounds, and ethical approval is granted.

Please note that, before you collect any data, you still need to obtain ethical and governance approval from any other authorities who have responsibilities for your participants or the circumstances in which you are working, for example, the NHS or prison authorities. In particular, any procedure involving neuroimaging must have governance and ethical clearance from YNiC*.

Please ensure that arrangements for obtaining informed consent, providing an appropriate de-briefing, and ensuring confidentiality of participants' data are fully implemented.

Andrew Monk

Professor Andrew Monk
Chairman of the Departmental Ethics Committee

* In the case of projects carried out at YNiC, all YNiC health and safety procedures must be followed to the letter. You should obtain consent from your participants using the YNiC consent and safety forms as well as the consent forms you specified with your application to this committee.

Appendix 2:

Department of Psychology

Departmental Ethics Committee

To: Kartini Abd Ghani and Susan Gathercole

From : Marcel Zentner

Date: 4 November 2010

Project: Working memory and learning and study skills in adult learners in different disciplines (a)

Thank you for submitting your research proposal for scrutiny by the Departmental Ethics Committee. I am writing to tell you that in principle the Committee has no objection to the proposal in principle on ethical grounds, and ethical approval is granted. However, please consider my concerns expressed towards providing personal feedback especially of a negative nature to your participants.

Please note that, before you collect any data, you still need to obtain ethical and governance approval from any other authorities who have responsibilities for your participants or the circumstances in which you are working, for example, the NHS or prison authorities. In particular, any procedure involving neuroimaging must have governance and ethical clearance from YNiC*.

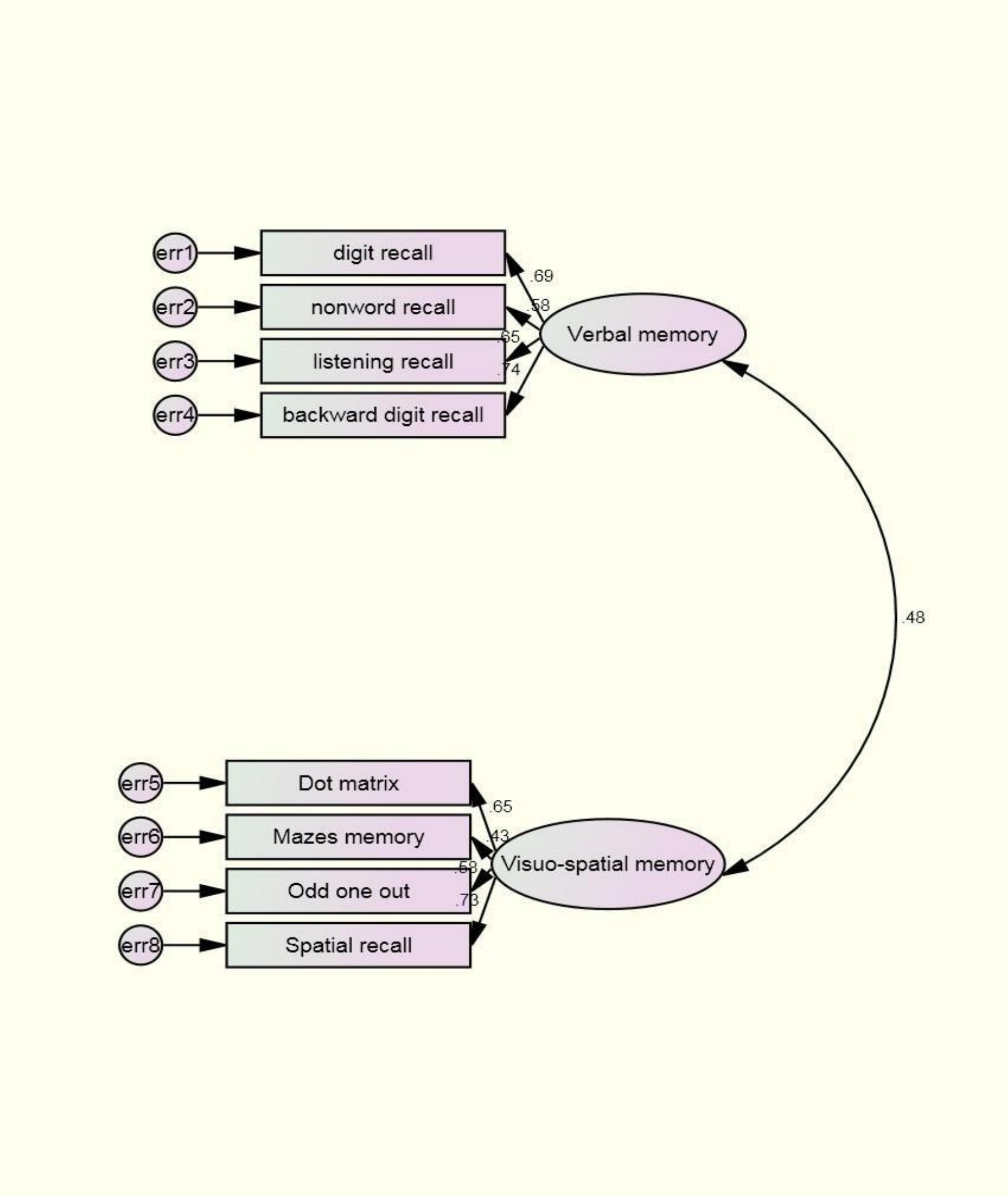
Please ensure that arrangements for obtaining informed consent, providing an appropriate de-briefing, and ensuring confidentiality of participants' data are fully implemented.

Dr Marcel Zentner
Chairman of the Departmental Ethics Committee

* In the case of projects carried out at YNiC, all YNiC health and safety procedures must be followed to the letter. You should obtain consent from your participants using the YNiC consent and safety forms as well as the consent forms you specified with your application to this committee.

Appendix 3:

Model 1: The diagram for 2-factor model based on the distinction between verbal and VS memory skills.



The Maximum likelihood Estimates:

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
VRWM_2	<---	Verbal memory	.740
VRWM_1	<---	Verbal memory	.653
VRSTM_2	<---	Verbal memory	.584

			Estimate
VRSTM_1	<---	Verbal memory	.690
VSWM_2	<---	Visuo-spatial memory	.732
VSWM_1	<---	Visuo-spatial memory	.584
VSSTM_2	<---	Visuo-spatial memory	.426
VSSTM_1	<---	Visuo-spatial memory	.651

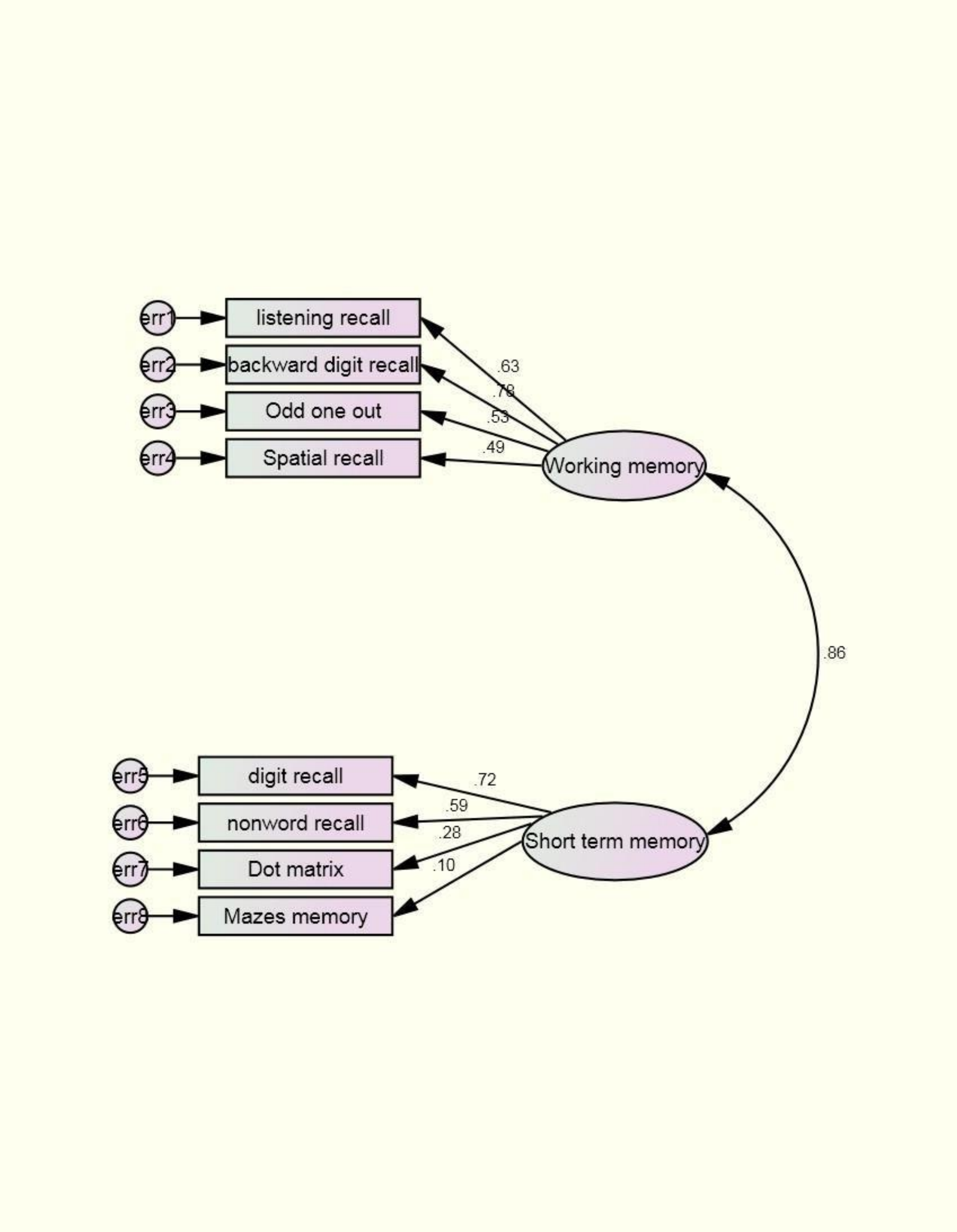
Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
Verbal memory	<-->	Visuo-spatial memory	53.998	17.124	3.153	.002	

Correlations: (Group number 1 - Default model)

			Estimate
Verbal memory	<-->	Visuo-spatial memory	.478

Model 2: A diagram for a 2-factor model corresponds to short-term memory and working memory.



The Maximum likelihood Estimates:

Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
VSWM_2	<---	Working memory	.489
VSWM_1	<---	Working memory	.535
VRWM_2	<---	Working memory	.785
VRWM_1	<---	Working memory	.634
VSSTM_2	<---	Short term memory	.098
VSSTM_1	<---	Short term memory	.278
VRSTM_2	<---	Short term memory	.587
VRSTM_1	<---	Short term memory	.719

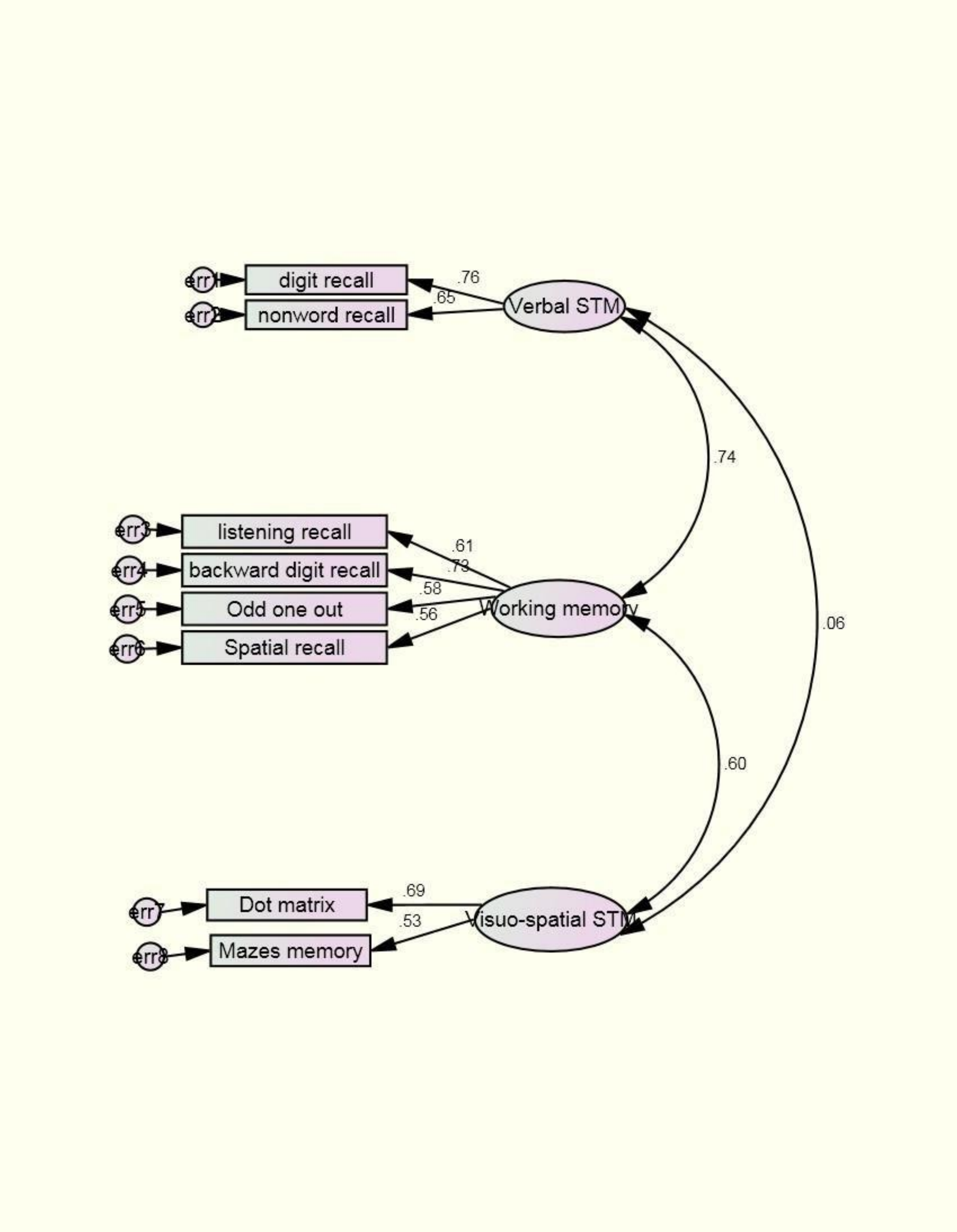
Covariances: (Group number 1 - Default model)

			Estimate	S.E.	C.R.	P	Label
Working memory	<-->	Short term memory	7.260	8.457	.858	.391	

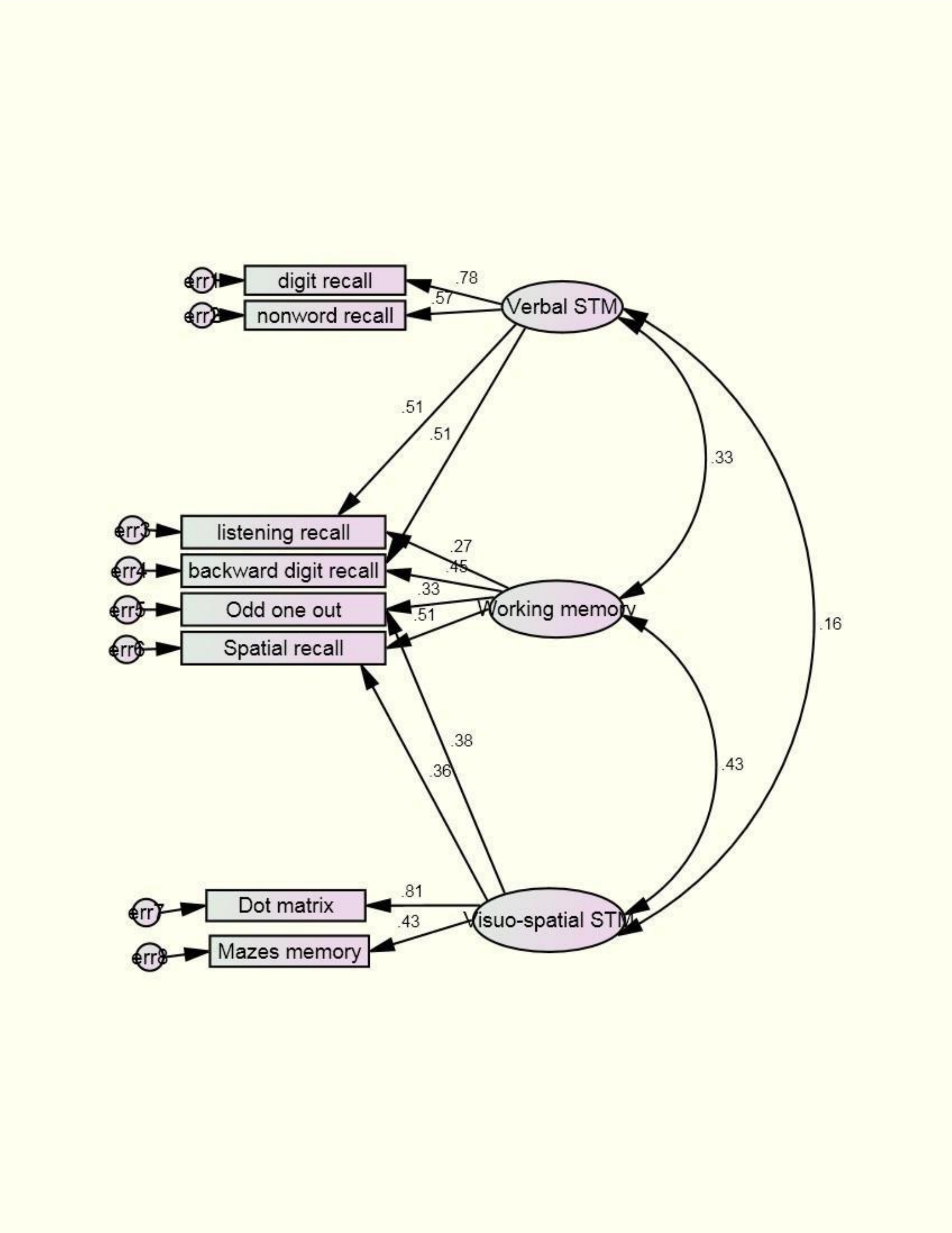
Correlations: (Group number 1 - Default model)

			Estimate
Working memory	<-->	Short term memory	.861

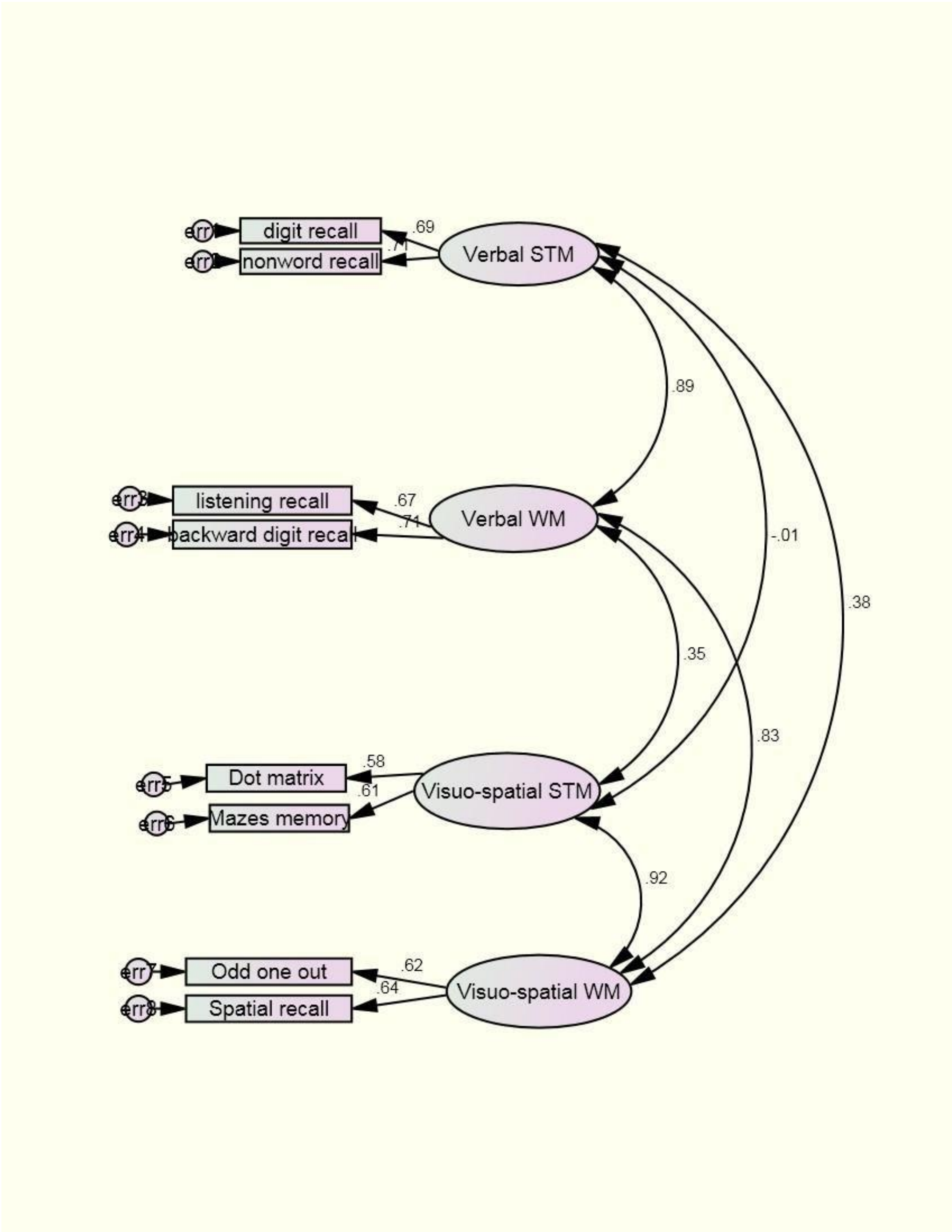
Model 3a: 3 factors – a single domain general WM factor and 2 separable storage factors for verbal and visuo-spatial STM correspond to B&H (1974) WM model and Engle et al (1999) model.



Model 3b: 3 factors – a single domain general WM factor and 2 separable storage factors for verbal and visuo-spatial STM correspond to B&H (1974) WM model and Engle et al (1999) model (based on common processing factor for verbal and visuo-spatial WM tasks and domain specific factors for verbal and visuo-spatial storage). (All participants – all processing path were fix equally to 1)



Model 4: Path model for 4 factors with separate domain-specific WM & STM constructs (Freidman & Miyake, 2000; Miyake et al., 2001). (All participants - All the path between latent constructs and their variables were fixed to be equal to 1) – probs with multico



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