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 weaknesses 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.
CONTENTS

Abstract ......................................................................................................................... ii

CONTENTS ..................................................................................................................... iii

List of Tables .................................................................................................................. vii

List of Figures ................................................................................................................ x

Acknowledgements & Dedication ................................................................................... xii

Author’s declaration ......................................................................................................... xiii

CHAPTER ONE ............................................................................................................... 1

LITERATURE REVIEW ................................................................................................. 1

1.1 Introduction ................................................................................................................ 1

1.2 Working memory: A theoretical framework ......................................................... 2

  1.2.1 Short-term memory and long-term memory .................................................... 4

  1.2.2 Working memory .............................................................................................. 4

  1.2.3 Multi-component model of working memory ............................................... 5

  1.2.4 Alternative models of working memory ....................................................... 11

1.3 Working memory measurement ............................................................................. 16

  1.3.1 Measures of verbal short term memory ....................................................... 16

  1.3.2 Measures of verbal working memory ............................................................ 18

  1.3.3 Measures of visuospatial short-term memory and working memory...19

  1.3.4 The Automated Working Memory Assessment (AWMA) ......................... 20

  1.3.5 Summary .......................................................................................................... 21

1.4 Working memory and learning .............................................................................. 22

  1.4.1 Working memory and learning ...................................................................... 23

  1.4.2 Working memory and learning disabilities/difficulties ............................... 25
1.5 Dyslexia .............................................................................................................28
  1.5.1 Theories of dyslexia ....................................................................................32
1.6 Working memory and dyslexia in higher education ..................................36
  1.6.1 Working memory, dyslexia and science learning .....................................38
1.7 Working memory and science .................................................................39
1.8 Other factors of success in learning: Study skills and learning styles .......43
  1.8.1 Learning and study skills .........................................................................43
  1.8.2 Learning styles .........................................................................................47
1.9 Working memory and general intelligence ..............................................51
1.10 Working memory intervention ..............................................................52
1.11 Overview of thesis .....................................................................................55
1.12 Outline of thesis .........................................................................................57

CHAPTER TWO ....................................................................................................59
WORKING MEMORY AND DYSLEXIA ...........................................................59
2.1 Introduction ....................................................................................................59
2.2 Aim and Hypotheses .....................................................................................59
2.3 Research Design ............................................................................................60
2.4 Study 1A .........................................................................................................61
  2.4.1 Method .......................................................................................................62
  2.4.2 Task materials/ Research instruments .....................................................62
  2.4.3 Procedure ................................................................................................69
  2.4.4 Ethical Issues ............................................................................................70
  2.4.5 Results ......................................................................................................70
  2.4.6 Summary ..................................................................................................76
2.5 Study 1B .........................................................................................................77
  2.5.1 Method .......................................................................................................78
  2.5.2 Task materials/ Research instruments .....................................................80
  2.5.3 Procedure ................................................................................................80
  2.5.4 Ethical Issues ............................................................................................80
List of Tables

Table 2.1  | Description of LASSI subscales: 67
Table 2.2  | Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 1A): 72
Table 2.3  | Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 1A): 73
Table 2.4  | Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by Disability Status (Study 1A): 74
Table 2.5  | Descriptive Statistics for Learning preference (ILS) as a Function of Group (Study 1A): 75
Table 2.6  | Correlation between standardised scores from AWMA: 75
Table 2.7  | Significant correlation between working memory and study skills measures: 76
Table 2.8  | Mean standard scores on reading, spelling and general ability for the dyslexic students based on their Psychological Assessment Report: 79
Table 2.9  | Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 1B): 81/82
Table 2.10 | Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 1B): 82/83
Table 2.11 | Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by Disability Status (Study 1B): 83/84
Table 2.12 | Descriptive Statistics for Learning preference (ILS) as a Function of Group (Study 1B): 85
Table 2.13 | Correlations between Working Memory measures and Learning Strategies for All Participants (Study 1B): 85/86
Table 2.14 | Factor loadings for the LASSI and AWMA: 87
Table 2.15 | Age, gender ratio of the groups of students (Study 1A & 1B): 89
Table 2.16 | Descriptive Statistics for the Working Memory Tasks as a Function of Group (Study 1B): 90/91
Table 2.17: Descriptive Statistics for the Cognitive tasks (WAIS-III) as a Function of Group (Study 1A & 1B)

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

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

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

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

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

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

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

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

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

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

Table 3.8: Descriptive Statistics for additional verbal and visuospatial tasks as a Function of Group

Table 3.9: Means, and Standard Deviations of Measures of Learning Strategies and Study Skills by Group (Study 2B)

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

Table 3.11: Correlations between working memory and other
cognitive ability measures and study skills for all participants using Pearson’s correlation coefficient

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

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

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

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>The flow of information through the memory system based on Atkinson &amp; Shiffrin (1968) modal model.</td>
<td>3</td>
</tr>
<tr>
<td>Figure 1.2</td>
<td>Multi-component working memory model with links to long term memory, based on Baddeley, 2000.</td>
<td>7</td>
</tr>
<tr>
<td>Figure 1.3</td>
<td>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).</td>
<td>12</td>
</tr>
<tr>
<td>Figure 1.4</td>
<td>Chemistry triangle (Johnstone, 1997).</td>
<td>41</td>
</tr>
<tr>
<td>Figure 1.5</td>
<td>The Learning and Study Strategies Inventory (LASSI) model (Weinstein et al., 2002).</td>
<td>45</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Mean scores for each subscales of LASSI by disability status.</td>
<td>84</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>A simple path diagram for 2-factor model based on the distinction between verbal and visuospatial memory measures.</td>
<td>125</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>A simple path diagram for a 2-factor model corresponds to short-term memory and working memory.</td>
<td>126</td>
</tr>
<tr>
<td>Figure 4.3</td>
<td>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 &amp; Hitch (1974) working memory model.</td>
<td>127</td>
</tr>
<tr>
<td>Figure 4.4</td>
<td>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 &amp; Hitch (1974) WM model.</td>
<td>128</td>
</tr>
</tbody>
</table>
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.

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

Figure 5.2  Types of mediation
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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.

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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 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; Reading, 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 psychologists 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 subvocal 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 back 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 Baddeley, 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
Chapter 1

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 rehearsal 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, maintenance 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 intermediary 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