PROSPECTIVE MEMORY IN ADULTS WITH DEVELOPMENTAL DYSLEXIA

ADAM P. ZIĘCIK

A thesis submitted in partial fulfilment of the requirements of London South Bank University for the degree of Doctor of Philosophy

October 2014

Dedicated to my wife Marta and my son Nikodem

Acknowledgements

I would like to take this opportunity to thank God for enabling me to complete this work. I am also very grateful for the support I have received from my wife, parents, family and friends. Also, I would like to mention here the financial support I have received from my parents (Krystyna and Jerzy Ziecik) without which accomplishing this task would not be possible. I would like to also thank Janette Jacobs (fellow PhD student) who supported me in many ways. She was my guardian angel at London South Bank University from day one. Overall, I am very grateful to my director of studies Dr James Smith-Spark and my second supervisor Dr Christopher Sterling, without whose guidance, knowledge, encouragement and support this research project would not have been possible.

Abstract

While short-term and working memory deficits in individuals with dyslexia are well documented, the effects of dyslexia on prospective memory (PM) have been neglected. A range of PM measures were administered to different samples of university students with and without dyslexia (typically N = 50, 25 per group, matched for age and IQ, and differing on reading and spelling measures). Questionnaire data indicated that individuals with dyslexia perceived themselves as significantly worse on everyday PM activities than non-dyslexics. These data were corroborated by ratings taken from close friends/relatives of the participants. Naturalistic data revealed that adults with dyslexia performed more poorly on a time-based task involving a delay of 40 minutes and 24 hours and an event-based PM task involving a one week delay. There were no event-based PM deficits in dyslexia in the experimental tasks. However, adults with dyslexia were significantly worse at time-based tasks. Difficulties with PM would, therefore, seem to be evident in adults with dyslexia and tend to manifest themselves in time-based PM tasks. This interpretation is consistent with executive functioning problems associated with dyslexia and theories that take a broader view of dyslexia than phonological processing alone.

Table of Contents

List of Tables

List of Figures

Chapter 1: Prospective memory

1.1. Definition of prospective memory

Prospective Memory (PM) is remembering to remember (Winograd, 1988) or remembering to perform an intended action (planned action) at an appropriate time in the future (McDaniel & Einstein, 2007). To successfully complete a PM task one needs to first form an intention to perform the task in the future, and then execute this task at the required time. Hence, some researchers refer to this type of process as realising delayed intentions (Ellis, 1996; Ellis & Milne, 1996). For instance, one needs to first form an intention to take out the *rubbish* later, when leaving for work, in order to be able to then perform this intended action when the appropriate time comes. Thus, a PM task always involves a time interval (also called a retention interval) between intention formation and intention execution, and this time interval can vary from short to long e.g. from two minutes to seven days.

There are two sub-components which constitute the performance of a PM task. These are the prospective and retrospective sub-components (Einstein & McDaniel, 1990; 1996). The retrospective component is known as the “what” and “when” of the PM task. The prospective component is the appearance of the thought in the cognizer’s mind regarding the PM response at the appropriate time (Einstein & McDaniel, 1996). For instance, in the example where one forms an intention to take out the *rubbish* later, when leaving for work, the retrospective sub-component is that it is the *rubbish* that one is intending to take out later, when leaving for work. The prospective sub-component in this example is to actually remember to recall this previously formed intention at the time when this action needs to be performed (Ellis, 1996; Graf & Uttl, 2001). After an intention to act in the future is formed, people usually engage in other tasks in the meantime (filled delay) before there is a need recall the intention. The lack of the recall of the prospective memory intention after a filled delay is one of the key reasons why prospective remembering fails. There are some processes which can help to improve PM performance e.g. rehearsal of the intention in tasks involving very short delays (West, Krompinger & Bowry, 2005).

1.2. Event-based vs. time-based prospective memory

There are two main types of PM tasks; time-based and event-based PM tasks (Einstein & McDaniel, 1990; Kliegel, Martin, McDaniel & Einstein, 2001). A time-based PM task involves performing the intended action at a certain time (called pulse intentions, see Ellis, 1988) or after a particular period of time has elapsed (called step intentions; see Ellis, 1988). The time-based PM tasks require participants to provide PM response after a certain amount of time has elapsed, usually involving a window of time where the response is required. The performance of an event-based PM task involves performing the intended action at the occurrence of a specific target event also called a PM cue (McDaniel & Einstein, 1993). This target event triggers associated PM activity regardless of an individual's engagement in other concurrent tasks (Einstein & McDaniel, 1996). The previous example of taking out the *rubbish* can be modified slightly to demonstrate these two types of PM. A time-based task would involve forming an intention to take out the *rubbish* at 7am tomorrow (involving a specific time), whereas an event-based task would involve forming an intention to take out the *rubbish* when one's spouse places it next to the front door (involving a specific event which acts as a cue). Generally experimenters mostly follow the aforementioned paradigms of event-based and time-based PM in controlled laboratory tasks (e.g. Einstein, McDaniel, Richardson, Guynn and Cunfer, 1995; Sellen, Louise, Harris & Wilkins, 1997). However, a PM task can also be activity-based, such as asking participants in advance to undertake another task after a particular experimental activity has finished (Kliegel, McDaniel & Einstein, 2000). In everyday life an example of an activity-based PM task could include intending to take out the rubbish after vacuuming one's home.

Einstein and McDaniel (1990) investigated event-based PM experimentally. This study aimed to investigate if there were any differences in the PM of younger and older adults and whether factors such as the availability of external aids and familiarity of the target event influenced performance. The results did not reveal any age-related deficits in PM regardless of the familiarity of the target cue and availability of external cues, with all participants remembering prospectively on average 61% of time. They argued that not all PM tasks are high in terms of the reliance on self-initiated retrieval (relying on oneself to retrieve a memory), but instead that PM tasks vary in the degree to which they rely on self-initiated retrieval. Time-based prospective memory tasks are argued to be generally harder to remember than event- based tasks, as time-based PM is self-initiated and requires the passage of time to be monitored (Einstein et al., 1995). In event-based PM, the tasks are automatically triggered by an external PM cue. This division enabled Einstein and McDaniel to argue that the tasks which they used (i.e. event-based) may not produce large age-related effects, as these tasks employ external cues which can serve as a guide for retrieval. On the contrary Einstein and McDaniel suggested that time-based PM tasks might be more likely to result in large age-related deficits, due to their greater reliance on self-initiated retrieval relative to event-based PM tasks. This was argued to be due to time-based PM tasks requiring participants to remember to monitor and initiate the PM response on their own.

Einstein et al. (1995) investigated whether there are any age-related differences between time- and event-based PM tasks i.e. PM tasks relying on self-initiation (time-based) or PM tasks relying less on these processes (event-based). Participants were engaged in an ongoing task, requiring them to answer general-knowledge questions. Before the ongoing task, participants were instructed to remember to press the F8 key every time the word *president* appeared within the question (implementing event-based PM). This experiment also involved some time-based PM tasks, where participants were asked to remember to press the F8 key after 5-minute periods had elapsed, with this task concurrently running alongside the presentation of the general-knowledge questions. In addition, both tasks included a distracter activity in the form of a vocabulary task. This distracter activity was presented after the instructions to remember to press the F8 key on the required occasions and before beginning the general-knowledge-question task. The event-based and time-based PM tasks used by Einstein et al. (1995) both included an equal number of targets (the word “president” appeared six times and there were six five-minute segments). Age differences were found in time-based PM tasks only i.e. older adults performed worse on tasks involving more self-initiation in comparison to younger adults. This study provided empirical evidence suggesting that event-based PM tasks differ from time-based PM tasks, supporting claims that these two types of tasks involve different levels of self-initiated retrieval.

Other investigations of PM have also indicated that there are substantial and reliable differences between event- and time-based PM tasks. For example two experiments conducted by Park, Hertzog, Kidder, Morrell and Mayhorn (1997) employed a working memory (WM) task as their ongoing task. Working memory is a multi-component, limited-capacity system responsible for the temporary storage and processing of information (i.e. manipulation, integration and maintenance; Baddeley, 1997; see section 1.5.2.1. for more information). Park et al. (1997) asked participants to perform either an event- or time-based PM activity in addition to the WM ongoing task. Control participants were also employed to perform either the WM or PM task only. Results showed age-related differences on both types of tasks (time- and event-based), but these differences were greater on the time-based PM task. However, the event-based PM task was found to have a higher cost to performance on the ongoing WM task compared to the time-based PM task. The authors argued that this might be because event-based PM tasks have a substantial attentional requirement related to continuous monitoring for PM cues.

Please note that majority of research has concentrated on event-based PM, although it is recognised that time-based PM performance has been extensively explored using the Virtual Week task which is a board game (or computerised task) simulating common everyday life PM tasks (Rendell & Craik, 2000). According to Hicks, Marsh and Cook (2005) it is unclear why only a handful of articles have appeared on time-based PM.

1.3. Paradigms used for investigation of prospective memory

1.3.1. Experimental paradigms

Laboratory based enquiries into PM can either involve dual-task paradigm or task-switch procedures (Bisiacchi, Schiff, Ciccola & Kliegel, 2009). Both of these paradigms comprise of an ongoing activity (a task performed during the time intervals between intention formation and execution; Ellis & Kvavilashvili, 2000) and the PM task itself in order to mirror the real-world nature of PM. Namely, remembering prospectively in real life involves other secondary tasks in which one is engaged e.g. having to remember to take out the rubbish when leaving home needs to be held in memory while getting ready for work. The dual-task paradigm requires participants to perform both the PM and ongoing tasks simultaneously (e.g. Hicks et al., 2005). However, PM tasks employing dual-task paradigm could be argued to be different than a typical dual-task design in which one has two clearly cued activities to interweave. In PM tasks, only the ongoing task is clearly cued, but not the PM task which needs to be recalled. The task-switch procedure involves breaking out of ongoing activity in order to perform the PM activity i.e. participants are not required to respond to the ongoing task when they encounter a PM event (e.g. Burgess, Scott & Frith, 2003).

Experimental paradigms involving time-based and event-based PM tasks, in order to be in line with real life demands, use a cover task (also known as an ongoing activity) which may involve a number of different activities between the formation and execution of the intentions. These tasks do not involve explicit instructions regarding the intention, at the time of required remembering. In prospective memory experiments researchers (e.g. Gordon, Shelton, Bugg, McDaniel & Head, 2011) usually measure the accuracy and reaction time (RT) of responses to PM and ongoing trials. The measurement of the accuracy and RT of the ongoing task enables the investigation of possible costs to the ongoing task caused by having to perform PM tasks.

There have been a number of studies conducted under laboratory controlled conditions where PM tasks were embedded in ongoing activities, and performance of the ongoing activities have been required to be interrupted or suspended to allow execution of the PM tasks (e.g. Einstein & McDaniel, 1990; Einstein, McDaniel, Thomas, Mayfield, Shank, Morrisette & Breneiser, 2005; Kvavilashvili & Ellis, 1996).

1.3.2. Naturalistic paradigms

Prospective memory can be also investigated using naturalistic paradigms (e.g. Moscovich, 1982; Mecham & Leiman, 1982; Rendell & Henry, 2008; Rendell & Thomson, 1999). Naturalistic paradigms relating to daily life protocols are described by Bolger, Davis and Rafaeli (2003, p.580) as intended to "capture life as it is lived'. Therefore, daily life investigations aim to describe phenomena in their usual and natural settings. According to Reis (2012), the daily life approach is an important method of studying psychology, since psychological phenomena are more or less (depending on the phenomenon) influenced by the context in which they occur. The use of a naturalistic investigation allows the capture of the psychological phenomenon as a whole, including its contextual factors. Furthermore, Reis (2012) claims that in order to understand a behavioural process properly, it is necessary to take into account its contextual factors. Naturalistic measures have been also valued for their elimination of retrospective biases where one is self-reporting events by looking back at them with a predetermined and inaccurate perspective (Reis, 2012). For example, it is likely for a participant who generally believes that his or her memory is bad to rate his or her own memory failures within the last six months to be high, regardless of whether this is true or not (see section 1.4.4. of Chapter 1 for a consideration of this in relation to PM). The study of daily life has a very strong ecological validity and this makes its findings more applicable to practitioners e.g. as a basis for possible interventions (Hektner, 2012). Finally, Reis (2012) concludes that naturalistic methods to study daily life acquire a completely new level of information, which is more holistic compared to traditional methods and that these methods are increasingly important to researchers.

Naturalistic and semi-naturalistic research methods have been applied to study PM in order to provide a more ecologically valid and integrative approach. The use of naturalistic research methods is also necessary to investigate longer delays between intention formation and execution, which are too long for laboratory-based investigations (McDaniel and Einstein, 2007). The daily life study of PM enables a PM cue to appear as a natural part of another task or situation as well as involving the interruption of a daily routine or activity i.e. breaking out of an ongoing activity (necessary characteristics of PM tasks; Kvavilashvili & Ellis, 1996). Naturalistic and semi-naturalistic techniques have been used to investigate PM in a wide range of different populations e.g. pregnant women (Rendell & Henry, 2008); elderly adults (Masumoto, Nishimura & Tabuchi, 2011; Rendell & Thomson, 1999); individuals with amnestic mild cognitive impairment (Delprado, Kinsella, Ong & Pike, 2013); mild cognitive impairment (Schmitter–Edgecombe, Woo & Greeley, 2009) and autism spectrum disorder (Altgassen, Koban & Kliegel, 2012).

Early work using naturalistic PM tasks, for instance, involved participants being instructed before leaving the laboratory to call the laboratory at a certain time several days later (Moscovitch, 1982), or giving them a pack of postcards to be mailed on certain days (Mecham & Leiman, 1982). Such studies require participants to interrupt their daily routine in order to perform the PM tasks and thus breaking out from the ongoing task is achieved naturally, as tasks performed in real life conditions appear as a natural part of another task or situation. However, these studies have been criticised for a lack of accuracy and low precision in the measurement of PM, since the precise time of performing the prospective activity was not recorded. In more recent research on PM, this problem has been mitigated by the use of more advanced technology. For instance, mobile phones (e.g. Masumoto, Nishimura & Tabuchi, 2011) or answering machines (e.g. Delprado, Kinsella, Ong & Pike, 2013) have been used in a number of investigations. The advantage of using such technologies allowed the date and time of calls placed to be recorded. Other studies have used portable time-logging devices where participants were required to log the time at prescribed times over a number of days (Rendell & Henry, 2008; Rendell & Thomson, 1999).

Sellen et al. (1997) also compared performance of adults on naturalistic event- and time-based PM tasks conducted within the workplace of participants. Electronic badges recorded the PM responses over a two week period. Participants were required to press a button on the budges every two hours for the time-based PM task and every time they entered a particular room for the event-based PM task. Participants also pressed different numbers and pattern of buttons on the badge to record the amount of times that participants though about the PM tasks. The results showed enhanced performance on the event-based task in comparison to the time-based task. Sellen et al. proposed that event-based cues are external and therefore are a better trigger for the intended action compared to time-based cues, which are internal. In this study participants tended to think about the time-based PM task more frequently compared to event-based PM task.

Another type of naturalistic inquiry into PM involved a self-generated PM task. Delprado, Kinsella, Ong and Pike (2013) asked participants to identify their own PM tasks for the coming week and after that week had elapsed they were asked whether or not they had remembered to do the tasks. This study investigated participants with amnesic mild cognitive impairment and found this group to be impaired on PM tasks compared to healthy controls. All participants were found to use strategies (e.g. a written note) that aided memory in around 50% of the time, when engaging in their own tasks. Prospective memory investigations using participants' own self-generated PM tasks have been argued to be more ecologically valid. Nevertheless, this type of naturalistic design still relies solely on self-reports provided by participants. This issue of using self-reported data lowers the validity of a study, as there is no way of investigating whether participants actually performed the tasks.

To improve the validity of tasks which rely on self-reports researchers have used semi-naturalistic PM tasks which require participants to do everyday life activities, while present in the laboratory or similar experimenter-generated environment. For instance, Craik and Bialystok (2006) employed a Dresden Breakfast task where participants had to remember to prepare a breakfast by remembering when to start and stop cooking five foods, so that all the foods would be ready at the same time. Participants also engaged in an ongoing distractor task (i.e. setting the table in a particular way). This study found age related decrements in most measures. However, the ecological validity of semi-naturalistic tasks can be lower than that of naturalistic tasks. This may be because participants are more aware that they are being watched, as the tasks do not take place in real life settings (i.e. in the participants' own homes). Nevertheless, semi-naturalistic tasks are more ecologically valid than traditional lab-based measures, because they take place under real life conditions.

1.4. Theories of prospective memory

The most prominent theories regarding PM are related to the mechanisms which allow the retrieval of PM; these are mainly relevant to event-based PM. Less research has been conducted with regards to time-based PM (Hicks, Marsh Cook, 2005) and there are no major theories specifically concerning time-based PM. Nevertheless, some of the PM event-based theories are also relevant to time-based theories. According to McFarland and Glisky (2009) time- and event-based PM tasks require many of the same processes e.g. recalling an association between PM intention and cue, as well as dividing attention between ongoing and PM tasks. Thus, some theories would be relevant to both PM task types, such as theories of event-based PM which are not cue-focused e.g. the reflexive-associative theory (e.g. Einstein & McDaniel, 1996). Some of the cue-focussed theories (e.g. The Preparatory Attentional and Memory; PAM theory; Smith, 2003) may be also relevant to time-based PM, as time-based tasks may also require recalling an association between PM intention and cue (McFarland & Glisky, 2009). For example, the time or a clock can act as a cue in time-based tasks. This type of cue could be argued to be more general compared to event-based cues as a specific time could remind one about many activities whereas a specific event is more likely to remind one about a specific PM intention. However, in some time-based tasks there may be no time cues available, such as a clock which may help activate the time-based PM activity. This reasoning is in line with the researchers (e.g. Craik, 1986; Einstein et al., 1995) who claimed that time-based PM tasks require more self-initiated processing compared to event-based tasks. Since time-based PM requires participants to remember to monitor and initiate the PM response on their own, whereas in event-based PM tasks cues act as reminders i.e. as event-based PM cues remind participants about the PM activity. Even if participants were not monitoring at the beginning of a task, it is possible that after the first event-based PM cue appeared they were reminded about the PM task and as a result started monitoring. McFarland and Glisky (2009) have also suggested that time-based PM tasks may require more monitoring processes (time monitoring) as there are no external cues to direct responding and thus one needs to monitor frequently for an appropriate time to perform the intended action. Thus, time monitoring was argued to involve continual interruption of ongoing activities and was suggested to be mainly self-initiated. Some event-based PM tasks were argued to only involve interruption and inhibition of the ongoing task once the PM target was recognised, whereas other event-based PM tasks were argued to involve monitoring processes. Thus, there are two main theories which concern mechanisms that allow the retrieval of event-based PM. The first is the monitoring theory (Einstein et al., 2005). The second theory is named the spontaneous retrieval theory (Einstein & McDaniel, 1996; Guynn, McDaniel & Einstein, 2001; McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein & Breneiser, 2004). McDaniel and Einstein (2000) have tried to incorporate the former two major theories and given this theory the name of the multiprocess framework. These theories of PM retrieval will be discussed in this section.

1.4.1. Prospective memory considered from the perspective of memory-based models

Prospective memory can be understood from the perspective of memory-based models. Considering PM in this way, the PM intention is stored in memory as declarative knowledge (conscious recall of memories related to facts and events) and plays a causal role in action. The probability of the intention being retrieved is reliant on the level of activation of the representation and the presence of appropriate retrieval cues. Memory representation which is fully activated will result in recall and in turn successful performance of the intended activity, as long as the activity was correctly encoded. Intention has been described by Reason (1983) as a collection of critically active cognitive schemata. In order for the cognitive schemata to be activated, they need to be refreshed by periodic reviews of intention, and failure to do this will result in these cognitive schemata decaying spontaneously (Reason, 1983), and ultimately one would fail to perform the PM activity.

In contrast to Reason (1983), Goschke and Kuhl (1993; 1996) argued that cognitive schemas related to PM intentions have a special dynamic status in memory. They proposed the intention-superiority effect on the basis of experiments in which participants recognised words which were related to an intended action faster and more accurately than neutral words. On the basis of this evidence the authors argued that an intention is represented at a higher level of activation. This effect has been argued to provide unintentional enhancement of the activation level of intention-related concepts. The subsequent research in the area of intention-superiority effect was most notably conducted by Marsh and colleagues (e.g. Marsh, Hicks & Bryan; 1999), but also by Freeman and Ellis (2003).

Tobias (2009) argues that PM memories decay at the same rate as retrospective memories (recollection of episodes that occurred in the past, including semantic, episodic, autobiographical and declarative memory). Tobias argues that reminders to perform PM tasks coupled with an individual’s level of commitment to undertake the task can assist in keeping the accessibility of the intention to mind. The habitual repeating of a PM task is argued to ultimately replace the need for memory aids.

1.4.2. The monitoring theory of prospective memory

The monitoring theory (Einstein et al., 2005) states that for a PM intention to be retrieved at the appropriate moment the cognitive system has to monitor the environment for target events. The monitoring process refers to holding the PM intention in mind and searching the environment for cues indicating that the PM intention should be executed (Scullin, McDaniel & Shelton, 2013). This monitoring requires attentional resources which are resource-demanding as the environment is searched for a signal confirming that the previously formed intention can be appropriately executed.

The PAM theory (Smith, 2003; Smith & Bayen, 2004) has been proposed as a more specified and stronger view of the monitoring theory. It assumes that event-based PM tasks continuously engage monitoring processes for successful completion and argues for a strategic, non-automatic preparatory process which monitors events for possible PM cues (Smith, 2003). This attentional process also plays a part in deciding between targets and non-target events as well as in recollection of the PM intention once encountered. According to Smith and Bayen (2004) preparatory processes are also involved in the rehearsal of the PM cue to which a PM response needs to be made. The PAM theory takes a strong view which argues that a PM task cannot be completed without preparatory monitoring processes. Moreover, Smith (2003) has stated that the retrieval of a PM intention cannot be automatic as it depends on non-automatic, strategic preparatory processes taking place during the retention interval between intention formation and execution. The PAM theory suggested that the preparatory attentional processes can either take the form of conscious strategic monitoring or may involve subtle attentional processing which still requires capacity, but might be outside of awareness (Smith, Hunt, McVay & McConnell, 2007).

Background evidence indirectly supporting the PAM theory comes from studies which found that dividing attention during retrieval has a negative impact on PM performance (e.g. Einstein, Smith, McDaniel & Shaw, 1997; Marsh & Hicks, 1998; McDaniel et al., 1998; Park et al., 1997). Smith (2003) argued that the decrease of PM performance found under such conditions can be understood to be due to dividing attention which hinders the executive monitoring processes required for recognition of PM cues. Smith (2003) showed empirical support for her claim in an experimental study investigating PM. One group of participants was asked to complete an ongoing task involving making lexical decisions as quickly as possible. The other group of participants not only had to respond to the ongoing task but also had to remember to respond to six event-based PM cues by pressing a key on the computer keyboard. Smith found that participants performing the dual-paradigm task (in the ongoing and PM tasks running concurrently) had significantly slower RTs when making lexical decisions (in the ongoing task), in comparison to responses of participants who were only engaged in the ongoing task. The increased RT to the ongoing task in the dual-paradigm condition was argued to be due to insufficient resources left over for this task, as the resources were engaged in monitoring for PM cues. This was further supported by participants whose increased RTs on the ongoing task were paired with PM performance above the mean. Therefore, monitoring for PM cues was shown to be associated with costs in the form of slower RTs on the ongoing task. Furthermore, because monitoring is resource-consuming, there also could be a cost of PM related monitoring shown in the form of errors in the ongoing task. On the basis of this, the PAM theory argued that preparatory attentional processes consuming limited cognitive resources result in cost to the ongoing task.

Smith (2003) conducted a series of three experiments which investigated the impact of performing PM tasks on ongoing activity. The first experiment involving two participant groups employed a lexical decision task as an ongoing activity (deciding whether a letter string is a word or non-word). Only one of the participant groups was asked to respond to six PM target words embedded in the ongoing trials. The other group was told that they did not need to respond to the PM cues until after the ongoing task had been completed. Smith (2003) argued that this design enabled an investigation of whether adding a PM task would have a cost to the performance on the ongoing trials, caused by the involvement of preparatory attentional resources required for PM retrieval. Smith reasoned that any cost visible on the ongoing trials of a task (which also includes PM trials) could simply be caused by the need to make a PM response in addition to, or instead of, engaging in the processes needed for the ongoing task performance. Therefore, this may not be indicative of engagement of preparatory attentional processes during the time interval between intention formation and its execution. Smith proposed that it is better to compare it to a task which does not require PM responses in order to investigate if preparatory attentional processes are engaged during the ongoing trials of a task which also incorporates a PM task, as it does not require preparatory attentional resources. The expected cost to the ongoing trials during the intention retention period was based on the PAM theory which stated that attentional preparatory processes draw on one's limited resources.

The results showed no significant differences in terms of PM accuracy between the two participant groups. However, it was found that the addition of the PM task resulted in a slowing on the ongoing task. This was argued to support the assumption of PAM that PM tasks require functional attentional resources even when the PM cues are not present (during the performance of the ongoing trials). The results from this experiment also showed that participants who were more accurate on the PM component of the task had slower responses to the ongoing trials compared to participants with poorer PM performance. This was argued to be due to a reduction of the attentional resources available, with participants who scored higher on the PM component having to direct capacity away from the ongoing task, in order to successfully perform the PM task. This supported the PAM theory, that the attentional preparatory processes are involved in successful event-based PM performance.

The second experiment conducted by Smith (2003) was aimed at providing further support for the PAM theory by replication of the main finding from the first experiment. The results supported the findings of the first experiment, in that the performance of a PM task had a negative impact on the ongoing task and therefore, it was argued that preparatory attentional processes are needed for successful performance of an event-based PM task. However, it was still unclear whether it was the initiation of PM intention that required capacity or other processes such as rehearsal of PM cues or action. In order to investigate this experiment three employed manipulation of the PM cue discriminability by the means of orthographic distinctiveness. Participants were also given a measure of WM to investigate if capacity is needed for retrieval of PM intentions. On the basis of the claim that orthographically distinct cues require more capacity to be processed as these cues have been found to be more difficult to process at the lexical level (Hunt & Toth, 1990), Smith argued that capacity would be involved in PM intention retrieval if participants with high WM span perform better on the PM task (especially in tasks with orthographically distinct PM cues) compared to participants with low WM spans. Smith argued that participants with high WM span would have enough resources to perform the ongoing task whilst maintaining the preparatory processes. She also stated that participants with high WM spans would be expected to make use of the increased memorability of the distinct cues, unlike participants with low WM spans who would not be able to take advantage of the orthographically distinct PM cue, as their limited WM capacity would be fully engaged on the PM tasks.

The results from experiment three confirmed that unlike common PM cues, participants with high WM spans were more likely to respond correctly to distinct PM targets compared to participants with low WM spans. It was also found that only participants with high WM spans improved significantly on the PM performance in the distinct PM cue condition compared to the common PM cue condition. The difference in the impact of the cues with different distinctiveness on the two participant groups (low and high WM spans) was argued to confirm that it is not only the retrospective recall of the PM action or its performance that requires capacity, but also the retrieval of the PM intention. Thus, the author claimed that the interaction of WM span and orthography supported the claim of the PAM theory, in that PM tasks involve capacity and therefore are non-automatic. The data were also reanalysed in order to see if they produced similar results to experiments one and two, in terms of PM performance and cost to ongoing task. This reanalysis showed the same pattern of results i.e. participants who were better at the PM task had slower RTs on the ongoing trials. The results of experiment three also showed that PM performance is dependent on how much resources are directed towards the PM task in comparison to the ongoing activity.

In general Smith's (2003) results provided support for the PAM theory and the proposition that preparatory processes as well as retrospective memory processes contribute to PM performance. It also supported the claims that event-based PM tasks are capacity-consuming and this is not just caused by the retrospective elements of the PM task or its performance, but by preparatory attentional processes. It showed that attentional resources are required before an event-based PM cue appears and that these resources are needed for the retrieval of the PM intention. Thus, the retrieval of event-based PM intention has been argued to be non-automatic. Smith argued that the engagement of attentional resources in PM task not only results in better PM performance but also creates costs visible on the ongoing activity.

The need for non-automatic processes for successful PM retrieval was further supported by the multinomial model of PM (Smith & Bayen, 2004). In this model the authors argued that a PM intention cannot be retrieved at all without engagement of preparatory attentional monitoring processes. The Smith and Bayen multinomial model of event-based PM is a formal mathematical model which enabled an estimation and validation of the extent to which the preparatory attentional processes and memory processes (responsible for recognising and distinguishing PM cues from non-cues) are involved in PM performance. Smith and Bayen used two separate and independent parameters for their multinomial model of PM. These were the preparatory attentional processes and retrospective memory processes.

They validated their multinomial model of PM in four experiments (Smith & Bayen, 2004) which manipulated the instructions in such a way as to place importance either on the PM or the ongoing task, distinctiveness of PM cues and the difficulty of PM cue encoding (based on the amount of time given for encoding). This model estimated that placing importance on PM task would lead to increased engagement in preparatory attentional processes (monitoring). On the other hand, this model estimated that placing more importance on the PM tasks would only have a little effect on the memory processes i.e. recognition of the PM cue. These effects occurred regardless of PM cue distinctiveness. Furthermore, Smith and Bayen argued that the effects of task importance which were found in relation to PM performance are mediated through varying levels of engagement in the preparatory attentional processes. This study also showed that when importance was placed on the PM task (in comparison to the ongoing task) there was a greater cost visible on the non-target ongoing trials. The manipulation of the amount of time participants have been given to encode PM cues showed that when participants were given more time, their PM performance increased. The multinomial modelling estimated that this manipulation of time available for encoding of PM cues affected the memory processes only. The Smith and Bayens' (2004) multinomial model of PM has been also validated successfully in a study conducted by Horn, Bayen, Smith and Boywitt (2011).

Later studies have also supported the claims of PAM theory that event-based PM tasks are capacity-consuming and involve non-automatic processes. For instance a study conducted by Smith, Hunt, McVay and McConnell (2007) has shown that performance of an event-based PM task results in cost to the ongoing activity. Salient PM cues were used in this study, as according to multiprocess theory of PM (McDaniel & Einstein, 2000; for more details see section 1.4.4.) they are likely to result in automatic retrieval of the PM intention. Smith et al. (2007) argued that if PM tasks with salient PM cues are automatic, no cost to the ongoing task performance will be visible. The results supported the hypothesis that PM tasks with salient PM targets interfered with the ongoing task performance and thus supported the argument that the retrieval of an event-based PM intention is not an automatic process. Similar task interference was found in time-based designs (e.g. Marsh, Hicks & Cook, 2006).

1.4.2.1. Criticisms of monitoring theory

The extreme version of the monitoring theory (i.e. PAM theory; Smith, 2003; Smith & Bayen, 2004) brings about possible criticisms. According to McDaniel and Einstein (2007) it may be too costly for attentional and supervisory resources to be involved in every event-based PM activity, especially when taking into consideration the number of potential ongoing intentions at any given time. Scullin, McDaniel, Shelton and Lee (2010) have also argued that monitoring is unlikely to be sustained over longer periods of time (see section 1.4.4.2. for more details). According to Bargh and Chartrand (1999) individuals have a limited capacity for conscious control over behaviours and this limited resource is likely to be quickly drained. Research has shown a negative effect of using up conscious effort in one domain on another domain in which participants were also required to sustain conscious effort (e.g. Baumeister, Bratslavsky, Muraven & Tice, 1998; Muraven, Tice & Baumeister, 1998). Therefore, Einstein et al. (2005) argued that it is rational to assume that individuals have a system allowing spontaneous retrieval in tasks with substantial time intervals between intention formation and its execution in order to not compromise performance of ongoing activities. Indeed, Einstein et al. (2005) have shown that monitoring for a PM cue is a controlled process which is hard to sustain over long periods. They argued that it is unlikely that individuals normally rely on constant and capacity-consuming monitoring processes in PM tasks involving longer time intervals and thus, investigated further the involvement of spontaneous retrieval processes in PM.

1.4.3. Spontaneous retrieval theory

The second main theory describing mechanisms of event-based PM is spontaneous retrieval theory (Einstein & McDaniel, 1996; Guynn et al., 2001; McDaniel & Einstein, 2000; McDaniel et al., 2004). Originally, Einstein and McDaniel (1996) proposed the noticing plus search model, where noticing the PM cue can spontaneously activate the PM intention. This model describes two stages on which event-based PM retrieval is dependent. Einstein and McDaniel claimed that a PM cue does not only need to be perceived, but it also needs to produce some internal response e.g. a feeling of general familiarity. The feeling of familiarity will be greater if the PM cue itself was used during the intention formation phase rather than just described in categorical terms. The second stage of the noticing plus search model proposed by Einstein and McDaniel (1996) relates to memory search (the meaning of event) which occurs after the event is noticed. This is similar to passing by someone who looks familiar but you do not recognise this person in the first instance. Upon searching your mind in an attempt to identify them, you realise that it is the postman. This theory suggests that the noticing phase is an automatic process, but the memory search is dependent on cognitive resources. The noticing and the memory search components have been seen as necessary stages for memory retrieval and have been argued to operate sequentially and separately (McDaniel, Guynn, Einstein & Breneiser, 2004). This point of view has been supported by West and colleagues (e.g. West, Herndon & Ross-Munroe, 2000; West, Herndon & Crewdson, 2001) who, using event-related brain potentials (ERPs) studies suggested that there are two different neural processes; one supporting the noticing of a PM cue and the other being memory search (i.e. retrieval of the intention from memory). On the basis of this noticing plus search model it can be argued that event-based PM forgetting can arise from either failure to notice the PM cue or a failure to search memory in order to establish what the cue signifies.

The noticing plus search model was further developed and was encompassed by the spontaneous retrieval theory (Einstein & McDaniel, 1996; Guynn et al., 2000; McDaniel & Einstein, 2000; McDaniel et al., 2004). This theory proposes that the retrieval of intentions occurring when PM cues are encountered relies on spontaneous memory-based and/or attentional processes. This process of retrieving PM intentions is thought to be much more automatic than the retrieval processes argued by monitoring theory (e.g. McDaniel & Einstein, 2007). The spontaneous retrieval theory proposes that one does not need to monitor the environment for PM cues; instead the PM intention retrieval occurs upon encountering a target event. In other words a previously formed intention can "pop" into ones mind when encountering a target event, and there is no requirement for these intentions to be kept conscious. It is argued that it is the target event that triggers remembering and that this process does not incur a cost on the ongoing task. Namely, the retrieval of a previously formed intention can take place without executive resources being dedicated to it when the PM cue first occurs. McDaniel, LaMontagne, Beck, Scullin and Braver (2013) using functional magnetic resonance imaging (MRI) methods have shown that spontaneous retrieval does not require the preparatory activation of the prefrontal cortex (PFC, an area of the brain to which executive processes have been mapped). The spontaneous retrieval theory, however, suggests that one may think about the intended action during the time interval between action formation and execution.

The spontaneous retrieval theory is supported by a study using self-reports conducted by Reese and Cherry (2002). In this investigation participants were asked at different points during a PM experiment to tell the experimenter what they were thinking about in these given moments. The results from this investigation showed that participants seldom mentioned the PM task while performing the PM experiment. It was found that participants mentioned thinking about the PM task during the experiment less than 5% of the time compared to 69% of the time in the case of the ongoing task. These results were found despite the adults participating in this study having relatively high PM accuracy (on average about 60%). Einstein et al. (2005) argued that if there was in fact, a strategic monitoring process involved for monitoring during the ongoing activity for PM cues, then thoughts about the PM task should be much more frequent. Alternatively, considering that participants reported thinking about the PM task seldomly, and did not rely on strategic monitoring processes, there should be overall poor PM performance. This however was not the case as participants had a respectable PM performance. Further support for the spontaneous retrieval theory comes from post-experimental self-reports in Einstein and McDaniel's (1990) study. These introspective reports revealed that the PM action "popped" into the minds of participants while they were engaged in the ongoing task.

Nowinski and Dismukes (2005) found a contextual effect which also supports the spontaneous retrieval theory. In their experiment, participants were presented with several diverse ongoing tasks but PM instructions were given only in the context of one of these tasks. In tasks where the contexts were given, the instructions about the PM task (PM intention was encoded, so that the task encountered at retrieval was the same as the ongoing task during encoding) resulted in better PM performance. It was argued that the restrained context at retrieval played the role of a facilitating agent in retrieval of the association between the PM cue and the target.

Einstein et al. (2005) conducted a series of experiments showing that spontaneous retrieval processes on their own can result in successful PM retrieval. They found that there was no cost to the ongoing activity associated with the performance of the PM task. This evidence opposes the findings of Smith and her colleagues regarding cost (e.g. Smith, 2003; Smith et al., 2007; 2010). More importantly, experiment five of Einstein et al. (2005) showed that spontaneous retrieval took place even in a task that did not require participants to perform a PM task (in which the PM intention was suspended). This was based on a claim that a spontaneous process should occur even without intention. To investigate this Einstein and colleagues gave their participants PM instructions, but before the PM task began they asked participants to perform a lexical decision task. This enabled the researchers to implement a design in which the PM intention was suspended during the lexical decision task. In this lexical decision task presented to participants between the PM instruction and the actual PM task, there were PM cues, but participants were instructed to ignore them. In addition, some of the other items in the lexical decision task were items that participants had previously encountered as the experimenters presented these in a previous task. The rest of the items in the lexical decision task were neutral items. This study also included a control condition which involved a retrospective memory (RM; memory of items/events encountered or experienced in the past; Baddeley, Eysenck & Anderson, 2009) demand instead of the PM demand. Einstein et al. (2005) assumed that participants would not monitor for the PM cues as there were instructed to ignore PM cues in the intervening lexical decision task. The results confirmed this, as almost the same RTs were found to the neutral items in the PM and RM control conditions. There were also no significant RT differences between the PM and RM tasks on the previously presented words. In addition, no significant differences in RTs between the PM and RM conditions were found when combining the two types of words (neutral and previously presented). The authors argued that this showed that no monitoring was employed in the PM condition. This was established on the basis that there was no reason to monitor in the RM condition, and the RT comparison of RM and PM conditions showed similar RTs in both of these conditions. Previous experiments which supported PAM theory (e.g. Smith, 2003) showed that when participants employed preparatory attentional processes, slowing was visible on the ongoing trials of the PM condition compared to the ongoing trials in the control condition and this was not the case in the Einstein et al. study.

Once the experimenters established that there was no involvement of monitoring processes during the lexical decision task, they were able to investigate whether spontaneous retrieval processes took place. To do this, the authors compared the RTs of the trials including PM cues to the trials with previously presented items (control items). This was the most appropriate comparison considering that both of these item types were encountered by the participants previously. Thus, this comparison enabled the researchers to equate the levels of repetition priming between the two stimuli types. The experimenters also compared the two memory type conditions (PM and RM). The results showed that participants' RTs were slower under the PM condition compared to the RM condition and, the RTs from the target items were significantly longer compared to RTs from the previously presented items i.e. participants were slower responding to the target items. This result supported the claim that spontaneous retrieval occurred in response to target events. There was also a significant interaction between the two factors (memory and item types) which showed that there was greater slowing (relative to previously presented items) for the PM targets compared to RM targets. This showed that there was a greater involvement of spontaneous retrieval when PM targets were processed compared to RM targets, ultimately indicating some involvement of spontaneous retrieval when RT targets were processed. This was argued to be due to participants noticing the familiar target in case of the RM targets. In the case of PM targets there could have been an additional slowing caused by retrieval of the intended action. The authors maintained that these results are very difficult to explain in the light of the PAM theory (Smith, 2003; Smith & Bayen, 2004) which claims that monitoring is always required in PM retrieval. Their results appeared to show the opposite i.e. that no monitoring was needed for event-based PM retrieval.

Einstein et al. (2005) proposed that the slowing might have occurred due to spontaneous noticing that these words in target trials are the targets during both conditions (PM and RM). This was argued to demonstrate the existence of spontaneous retrieval processes in a task where the PM demands were suspended. However, according to Marsh, Hicks and Cook (2008) the slowing in this experiment was related to the verification stage (where checking occurs to see if the cue meets the criteria) of the microstructure of an event-based response after cue detection rather than the noticing itself. This could mean that the spontaneous retrieval itself is an automatic process and that cognitive resources (as found by the slowing on the target trials) are needed for verification rather than for PM retrieval. This way of reasoning is consistent with

Einstein et al. (2005), who proposed that an associative mechanism (Moscovitch, 1994) is responsible for spontaneous retrieval (in both contexts, PM and RM). According to Moscovitch (1994) reflective retrieval is dependent on a strong association between a cue and action as well as full processing of the cue at retrieval. Furthermore, this is in line with Bargh and Chartrand (1999) who reasoned that the majority of human behaviours are automatically triggered as a response to some environmental stimulus rather than initiated by conscious will. The argument that spontaneous retrieval is an automatic process can be supported by studies suggesting that dividing attention in tasks which rely on spontaneous retrieval does not reduce PM performance (e.g. Guynn & McDaniel, 2007; McDaniel et al., 2004, Experiments 2 and 3). Considering that spontaneous retrieval is an automatic process, one would not expect dividing attention to have an effect on PM performance.

A more specific example of the spontaneous retrieval theory is explained by the reflexive-associative theory (Einstein & McDaniel, 1996; Guynn et al., 2001; McDaniel & Einstein, 2000; McDaniel et al., 1998, 2004). This theory attempts to explain the mechanics behind the spontaneous retrieval processes; stating that at the intention formation (stage one) an association is formed between the target event and the action to be executed. Once the target event is encountered the formed intention is brought to consciousness by an automatic associative-memory system (e.g. the hippocampal system has been suggested by Moscovitch, 1994), the previously formed association will initiate the retrieval of the PM action. This is said to happen regardless of whether the intention is present in consciousness or not. This automatic process of spontaneous retrieval has been claimed by Moscovitch (1994) to require few cognitive resources, to be obligatory and rapid. Nevertheless, this process is dependent on the quality of the formed association between the target event and the intended action, as well as on whether the target event is fully processed when encountered. The target event needs to be processed well enough to produce an interaction with a memory trace for the information that is associated with the target event to be brought into awareness. McDaniel et al. (2004) further stated that in the reflexive-associative theory the target event does not need to be necessarily recognised as a PM cue, as was proposed in the cue-focused theories covered so far in this chapter (e.g. PAM theory; Smith, 2003). The reflexive-associative theory has also claimed that it is not essential for the target event to be identified as significant in the first place in order for it to prompt a memory search later on. According to this theory the target event either triggers or does not trigger the intended action bringing it to consciousness via the reflexive-associative process. Therefore, it can be reasoned that a failure to form the requisite association could lead to PM errors.

Support for this theory comes from a study conducted by McDaniel et al. (2004) where pre-experimental associations were used to vary the associative interaction between the intended response and the target event. The PM task involved writing down associated words in response to each of two target words. The ongoing task involved rating words on different dimensions. There were two types of PM conditions in this experiment, the strong-association PM condition and the weak-association PM condition. In the strong-association PM condition participants had to write down words that were highly associated with the target words e.g. write down the word spaghetti to the target word sauce. On the contrary in the weak association PM condition, the word pairs were weakly associated e.g. staple-sauce. Even though the same words were used in both conditions, the strong-association condition resulted in 85% PM accuracy compared to 56% PM accuracy in the weak-association. Guynn, McDaniel and Einstein (1998) produced similar results in a study focusing on the association between the intended action and target event, finding higher PM scores when participants were reminded of both the PM cue and the intended action (associative link) in comparison to just being reminded about target events only (no associative link).

This theory does not refute the evidence supporting PAM, stating that dividing attention during the retrieval has a negative effect on PM performance e.g. Einstein et al. (1997); Marsh and Hicks (1998); McDaniel et al. (1998); Park et al. (1997). On the contrary, Einstein et al. (2005) claim that the findings obtained from these studies can also be explained through using the reflexive-associative theory. Namely, the claim is that dividing attention does not allow the full processing of the target event and in turn this makes it more difficult for the associative retrieval processes to recognise the target event and ultimately results in poor PM performance. Furthermore, Einstein et al. (1997) suggested that the deterioration of PM performance may not be due to dividing attention on the retrieval of intention stage but as a result of increased WM demands. Working memory capacity is a limited resource and therefore it may be demanding for one to hold the intended action at the same time as selecting the retrieved intention and scheduling the intended action.

1.4.4. Multiprocess theory of prospective memory

The multiprocess theory proposed that retrieval of PM can be dependent on multiple variables (McDaniel & Einstein, 2000). This view further argues that some PM tasks may be performed automatically by relying on environmental cues/conditions, but others require controlled monitoring of the environment on the basis of which switching of attention from the ongoing activity to the intended action occurs. Thus, this view argues that both strategic monitoring and spontaneous retrieval can underpin PM retrieval. The multiprocess view argues that it is not necessary that one has to monitor the environment for successful PM retrieval as suggested by PAM theory (Smith, 2003; Smith & Bayen, 2004), since retrieval can occur spontaneously. However, the multiprocess view accepts that monitoring can also underpin PM retrieval in contrast to the spontaneous retrieval theory presented previously.

According to Einstein and McDaniel (2000), the characteristics of the PM task, target cues (e.g. focality), ongoing task and individual differences can determine whether one is more or less likely to rely on spontaneous retrieval or monitoring process. Namely, it is the relation of the PM cue to PM activity and the nature of the ongoing task that plays an important role in establishing which process will be used (McDaniel & Einstein, 2007). Also the importance placed on the PM task can result in different processes being used for PM retrieval i.e. monitoring is likely if the importance of the PM task is emphasised. On the other hand, individuals may rely on the spontaneous retrieval processes when there is a focal PM cue (processing of the PM cue is encouraged by the ongoing task) and are more likely to rely on monitoring processes when the PM cue is non-focal (the ongoing task does not encourage its processing; see section 1.4.4.2. for more details about cue focality). In addition, salient PM cues are more likely to result in more automatic cue detection and less salient PM cues may require more monitoring. Another factor affecting the use of different processes is related to the strength of the cue-target association. A strong cue-target association encourages spontaneous retrieval compared to a weak cue-target association which is more likely to result in a monitoring approach. In addition, stretched WM resources (in the case of demanding or absorbing tasks) could result in the spontaneous retrieval approach to PM compared to high WM resources (in the case of non-demanding and non-absorbing tasks) resulting in individuals taking the monitoring route to performance of PM tasks (McDaniel & Einstein, 2007).

The multiprocess view also states that there is a general tendency for individuals to be more reliant on spontaneous retrieval processes compared to strategic monitoring. Due to the high volume of PM tasks that need to be accomplished in day-to-day life, one often needs to hold those intentions in memory simultaneously and for prolonged periods of time. Therefore, relying largely on monitoring processes to accomplish these PM tasks would be very taxing on limited WM resources. Moreover, the multiprocess theory, in line with contextualistic views of memory (e.g. Jenkins, 1979), proposes that the particular process that an individual relies on when performing a PM task is dependent on how the task was perceived. If an individual perceives the task to require spontaneous retrieval, he or she will be less likely to engage in monitoring processes. On the contrary, if an individual predicts that spontaneous retrieval is unlikely, they will be more likely to monitor.

The element of the multiprocess theory which takes into consideration the perception of task difficulty is similar to the attentional allocation view (Marsh, Cook & Hicks, 2006). The attentional allocation view states that after becoming aware of the difficulty of the task, participants develop an allocation policy based on the perceived difficulty of performing the ongoing and PM tasks. For instance, if an individual believes that the PM task is easy to perform, he or she will not allocate substantial attentional resources to it, whereas if a task is perceived as a difficult they are more likely to allocate additional attentional resources to such a task. The greater allocation of attentional resources could indicate employment of conscious monitoring strategies to accomplish a PM task, versus the reliance on spontaneous retrieval processes in tasks where fewer attentional resources have been allocated (McDaniel & Einstein, 2007). Marsh, Cook and Hicks (2006) argued that it is the changing belief about the difficulty of PM and ongoing task that plays a crucial part in the process of calibrating the allocation policy.

The effect of the changing belief about the difficulty of PM task has been demonstrated in a study conducted by Marsh, Hicks, Cook, Hansen and Pallos (2003). This experiment employed a lexical decision task as an ongoing task, with two conditions employing different versions of PM tasks. The first condition involved a PM task where participants pressed a key every time the word “dog” appeared (single cue word condition), whereas in the second condition participants were required to press a key every time a word representing an animal appeared (category condition). It was found that in the category condition there was a significant cost and interference effect on the reaction time of the ongoing task related to performing the PM task, where in the single cue word condition this effect was not significant (relevant to the control condition involving ongoing task only). The results have been argued to demonstrate that when the PM cue (“dog”) is clearly associated with the intention, it is likely that participants are more likely to engage in spontaneous retrieval processes as they will expect the target item to “pop out” at them (McDaniel &Einstein 2007). Thus, no cost related effects were found on the ongoing task performance. Conversely, in the category condition participants were more likely to believe that a monitoring approach would be more efficient in this task, as it may be insufficient to rely on spontaneous retrieval processes in order to successfully complete this PM task. This view has been reflected in the cost/interference effect found in the performance on the ongoing tasks in this condition. This study in turn supports the multiprocess theory of PM in that a variety of processes can be used when remembering prospectively.

The multiprocess view allows also the explanation of mixed findings regarding dividing attention i.e. some studies found that dividing attention has an effect on PM performance (e.g. Einstein, Smith, McDaniel & Shaw, 1997; Marsh & Hicks, 1998; McDaniel et al., 1998; Park, Hertzog, Kidder, Morrell & Mayhorn, 1997), whereas other studies found that it did not (e.g. Guynn & McDaniel, 2007; McDaniel et al., 2004, Experiments 2 and 3). Namely, in tasks which require or encourage monitoring, dividing attention can have an effect on PM performance that is different to performance on tasks which rely on spontaneous retrieval, where this negative effect is more likely to occur.

1.4.4.1. The dynamic multiprocess framework

The dynamic multiprocess framework proposed by Scullin, McDaniel and Shelton (2013) was developed as a result of a number of naturalistic studies which argued that levels of monitoring increase and decrease throughout the performance of an ongoing task (e.g. DeWitt, Hicks, Ball & Knight, 2012; Scullin, McDaniel & Einstein, 2010). Another important notion which contributed to the development of the dynamic multiprocess framework was that when monitoring is not reinforced (i.e. there is a lack of PM cues), monitoring processes are often terminated (e.g. McBride, Becker & Abney, 2011; Morgan, Weber, Rooney, Grant, Woods et al., 2012). These studies provided evidence that monitoring processes are not constant. Studies found that when participants were told that they can expect a PM cue during a specific context they monitored during that context, but they did not monitor for a PM cue under contexts where they did not expect the PM cue to appear (e.g. Marsh, Hicks & Cook, 2006; Scullin & Bugg, 2013). The dynamic mulitiprocess framework assumed that individuals selectively engage in monitoring when they enter into a context where the PM cue is expected (Scullin et al., 2013). According to Scullin et al. (2013) the dynamic monitoring theory is underpinned by a dynamic interplay between spontaneous processes and monitoring processes with selective remembering of when to monitor and when to not monitor. The authors of this framework argued that the process of spontaneous retrieval plays a key part when remembering when to monitor. The spontaneous retrieval can be either prompted by the onset of a particular context or other environmental cue.

In Scullin et al. (2013), participants in the experimental group were told that PM cue can occur in any context. Scullin et al. used 20 minutes and 12 hour time intervals in their investigation. The 12 hours interval included two conditions (nocturnal sleep and daytime awake). Participants were asked to complete a number of different tasks, some of which included PM cues. The series of tasks included three ongoing tasks during which two PM cues appeared. This study investigated monitoring patterns. The monitoring patterns were measured as ongoing task cost relative to a between-subjects control condition. The findings of this study supported the assumptions of the authors in that participants who remembered to perform the PM task monitored for the task, but not before the PM cue appeared. This study supported the dynamic interplay between spontaneous retrieval and active monitoring processes and claimed that if a participant spontaneously retrieves a PM intention when encountering a PM cue, monitoring is likely to occur following the successful retrieval, as one realises that a PM task can occur within this context. This indicated that monitoring is likely to occur if an individual suspects that a PM cue is likely to appear. However, when PM cues are not expected individuals will disengage from monitoring but are still able to respond to PM cues due to spontaneous retrieval processes. This point of view differs largely from the monitoring-only PAM theory (Smith, 2003) which claimed that sustained preparatory monitoring is necessary for successful PM performance. It supports the notion that a PM cue can bring about the intended action into one's memory spontaneously without the necessity of monitoring in a situation where the PM cue is associated with the PM action (e.g. Cona, Bisiacchi & Moscovitch, 2013; Rummel & Meiser, 2013).

1.4.4.2. Focality of cues in event-based prospective memory tasks

There are two types of PM cues which can be used in event-based PM tasks. The first type is focal. In a focal task there is an overlap between the information related to the ongoing task and the features of encoded PM cue so that the ongoing task encourages the processing of the PM task (Gordon et al., 2011). This means that the primary ongoing task and the PM task both involve the same type of processing (e.g. semantic). For instance a study conducted by Rendell, McDaniel, Forbes and Einstein (2007) illustrates a focal PM task where both of the tasks (ongoing and PM) involve the same type of processing. The ongoing task was to provide the names of famous people while viewing their pictures on a computer screen. The PM task in this experiment involved responding to a face of a famous person whose first name was John. Thus, in order to perform the ongoing task participants had to name the famous people shown to them and this encouraged the same type of processing of the stimuli as was required for the PM task.

Tasks where the processing of the ongoing task does not trigger the processing of PM cue features is termed non-focal. In this type of task, decisions made in the ongoing task involve a different kind of processing, which does not directly trigger the processing of the PM cue. Rendell et al. (2007) also employed a non-focal PM paradigm in their study of age related effects in PM. This task involved the same ongoing task in which participants had to provide names of famous people presented to them on a computer screen. The PM task involved responding to pictures of famous individuals who wore eyeglasses. In this way the ongoing tasks did not encourage the same type of processing of the pictures as was required for the PM task. This study compared the performance of younger adults to older adults across focal and non-focal PM, finding that older adults performed substantially less well on tasks involving non-focal PM targets compared to focal PM tasks, relative to younger adults. This indicated that these two types of event-based tasks may involve different processes.

The notion of focality itself is grounded in the transfer-appropriate processing theory of retrospective memory (see e.g. Roediger, 1996). This argues that when processing at retrieval matches processing at encoding, there is a greater chance of successful retrieval. The phenomenon was first demonstrated by Morris, Bransford and Franks (1977). In this study some participants encoded features of words phonologically whilst others encoded semantic features of given items. In comparison to participants who encoded semantically, participants who encoded phonologically were better on a subsequent rhyme recognition test where the earlier encoded words had to be checked for rhyme, against given words. Conversely, those who encoded the semantic features of items had better scores on a standard recognition test which was thought to depend on semantic information. This study found that memory improved when processing executed at encoding stage was the same as the processing preformed at the retrieval phase. This notion was then used in PM framework by Maylor, Darby, Logie, Della Sala and Smith (2002) who named it task-appropriate processing. Their study evidenced that when the ongoing task encouraged the same processing type at encoding and retrieval of PM cue (non-semantic-non-semantic or semantic-semantic), there were no age-related differences in the PM compared to when it did not encourage the same type of processing (non-semantic-semantic or semantic-non-semantic).

The task-appropriate processing concept was further extended by the multiprocess theory of PM (McDaniel & Einstein, 2000). The multiprocess view suggested that it is the overlap between the information about the PM cue that is considered during encoding and the information extracted from the PM cue at retrieval that makes spontaneous retrieval highly probable. This theory claims that if the ongoing activity supports processing features of the PM cue which are similar to these which were processed during intention formation, then it is very likely that spontaneous retrieval processes will occur. The multiprocess theory for the first time, pointed to the relationship between processing overlap and spontaneous retrieval processes. It also argued explicitly that there is no extensive need for engagement in monitoring processes for successful retrieval of PM under focal conditions.

The multiprocess view argued that it is not only important that the ongoing task encourages the same type of PM cue processing at the retrieval and encoding stages. This point of view represented by the task-appropriate processing concept has been extended in that the ongoing task needs to also encourage processing of the same features as those processed at the intention formation stage. Namely, it is not enough for the ongoing task to just encourage the same type of processing of PM cue at encoding and retrieval (e.g. nonsemantic-nonsemantic or semantic-semantic), but it also needs to encourage the processing of the features of the PM cue (McDaniel, Robinson-Riegler & Einstein, 1998). This can be demonstrated using an example of the word *bank* acting as a PM cue. Thus, if the PM cue bank is used in an ongoing task where, for instance, decisions need to be made about different kinds of services (e.g. bank or post office etc.), the PM cue *bank,* in order to be focal, would need to be encoded as an establishment that deals with money rather than bank as in the land alongside a river. This example demonstrates the claim of the multiprocess theory that it may not be enough for the PM cue *bank* to be processed semantically at the encoding stage and for the ongoing task to simply encourage semantic processing of PM target, but that it also needs to encourage processing of the same features of this PM cue as at the encoding phase. In other words, the ongoing task encourages the processing of specific features of PM cue and these features need to overlap with the features of the PM cue at encoding in addition to the overlap in processing type (nonsemantic or semantic) for the PM target to be focal. Another aspect related to the focality of a PM cue that extends the task-appropriate processing theory is that the multiprocess view also takes into consideration the extent to which the ongoing task points to the PM cue or focuses attention on it (Einstein & McDaniel, 2005). Moreover, the focality aspect described within the multiprocess framework has been stated by Altgassen, Vetter, Phillips, Akgun and Kliegel (2014) to enable manipulation of executive load in PM tasks. Namely, focal tasks require fewer executive attentional and WM resources then non-focal tasks in order to monitor for the PM cue.

In summary, the multiprocess view distinguished further the dichotomy between focal and non-focal PM cues. According to this theory focal PM cues overlap with the information constellation relevant to performing the ongoing task whereas the non-focal PM cues are not part of the information being considered by the participant, but PM cues are still present in the environment/visual field (McDaniel, Einstein & Rendell, 2008).

Cue focality has been established to have an effect on PM performance in typical populations (Roediger, 1996). Marsh, Hicks, Cook, Hansen and Pallos (2003) conducted a study exploring the effects of cue focality by employing focal and non-focal types of PM cues. In this study the ongoing task was a lexical decision task where participants had to decide as quickly and as accurately as possible whether the letter string presented on the screen was a word or a non-word. The PM task in this study was to press the "/" key every time the word *dog* (focal condition) or a word from the animal category (non-focal condition) appeared. This study effectively demonstrated the distinctiveness of the task-appropriate processing concept and focality concept established under the multiprocess view. The non-focal condition in this study included an ongoing task and a PM cue which were both based on semantic processing. However, to make a decision whether a letter string is a word or non-word participants did not need to process semantic features of the letter string, as it was not necessary when deciding whether the word belonged to animal category. This PM task is in line with task-appropriate principles (semantic-semantic type of processing at encoding and retrieval), but it does not portray a focal PM cue according to the multiprocess framework. This non-focal PM cue produced results expected for this type of task in comparison with a task with focal PM cue. The results of this study also showed that a focal PM cue (*dog*) resulted in better PM performance (93%) compared to a non-focal PM cue (animal category) which resulted in worse PM performance (78%).

A study conducted by Einstein et al. (2005, Experiments 1 and 2) investigated the effects of focal and non-focal PM cues on a sample of university students. In this study a category judgment task was used as an ongoing task where participants were shown two words, one in lowercase and one in uppercase. Participants had to make a decision on whether the lowercase word (e.g. tiger) was a member of a category presented by the use of uppercase word (e.g. ANIMAL). There were two types of PM tasks, one focal and the other non-focal. The focal ongoing task involved responding with a button press on the appearance of a single word (tortoise) whereas the non-focal condition required participants to press a key every time the syllable 'tor" appeared. In this example, the category judgment task does not foster awareness of the syllables present within each word, but instead encourages processing of the whole word. Therefore, it does not support focal processing of the target "tor', but it does encourage the processing of the target "tortoise'. The results of this study provided empirical evidence that focal PM cues result in a better response rate (91%) than non-focal PM cues (61%), with the focal condition proving to be easier to remember than the non-focal one. This study also found that the non-focal condition produced a significant cost to the ongoing task (task interference) whereas the focal condition did not and that participants were not monitoring for the PM cues in the focal condition. The authors claimed that focal cues are retrieved relatively spontaneously, which results in good PM performance with no or minimal cost to the ongoing activity.

Scullin et al. (2010) argued that it was possible that the differences in PM performance under focal and non-focal conditions found by Einstein at al. (2005), were caused by a greater difficulty to monitor for syllable targets compared to word targets rather than by cue focality itself. Scullin et al. (2010) conducted a series of experiments in order to investigate this further. In their first experiment the authors confirmed the alternative explanation of Einstein et al.'s (2005) results with the authors finding that syllables are more difficult to monitor for in comparison to words. In experiments 2a and 2b the researchers identified cues which were fairly equivalent in terms of the monitoring difficulty. Experiments 3 and 4 were designed in order to allow an investigation of the impact of focal and non-focal PM task condition on PM and ongoing task performance. This was achieved with the use of an initial-letter cue acting as a non-focal cue and a word cue serving the function of a focal cue. The ongoing task used was a lexical decision task which was argued to direct attention towards focal processing of the word cue but not the initial-letter cue. The results from these investigations showed that despite matching cues on monitoring difficulty, the non-focal condition resulted in a significant cost to the ongoing task compared to the focal condition which did not.

Scullin et al.'s (2010) study provided support for the multiprocess theory (McDaniel & Einstein, 2000) in that the focality of the PM cue determines the degree to which monitoring is needed for PM retrieval. The multiprocess theory proposed that focal and non-focal tasks rely on qualitatively different retrieval processes. Specifically, the PM retrieval in non-focal PM tasks requires monitoring in contrast to focal tasks, which are not dependent on monitoring. The authors argued this on the basis of significant task interference (in terms of cost to the ongoing task) in the non-focal condition and its absence in the focal condition. Scullin et al. argued that in the non-focal task participants required resources for monitoring purposes and this resulted in the task interference whereas, in the focal task there was no task interference indicating that no monitoring was engaged. According to Scullin et al., if the focal task engaged monitoring processes then task interference should be also found, similar to the non-focal condition. In addition, PM performance in this focal task did not differ significantly from the PM performance in the non-focal task indicating little or no monitoring needed for successful PM retrieval. This supports the multiprocess view that focal PM tasks rely on spontaneous retrieval processes and that non-focal tasks require monitoring processes. These results oppose the claims of the PAM theory of PM (Smith, 2003; Smith & Bayen, 2004) which claims that monitoring or other preparatory processes are always needed for successful PM retrieval. Furthermore, Smith et al. (2007) argued that resource demanding preparatory attentional processes are necessary for focal event-based PM tasks.

1.5. Involvement of executive functions in prospective memory

This section is concerned with behavioural and neuropsychological evidence supporting the relationship between PM and executive functioning processes (e.g. WM, inhibition, switching). There are also some links indicating that the supervisory attentional system (SAS), which is a part of Norman and Shallice's (1986) theory of action control, also plays a part in PM performance. Broadly speaking, EF processes as well as PM have both been associated with frontal cortical brain regions (e.g. Welsh, Pennington & Groisser, 1991; Burgess, Quayle & Frith, 2001). A brief description of EF, WM and the action control theory which includes SAS is provided before presenting the evidence supporting their involvement in PM.

1.5.1. Executive functioning

1.5.1.1. Executive functioning definition

Executive functioning refers to goal-directed (Anderson, 1998), organisational/control-based (e.g. Ardila, Pineda & Rosselli, 2000; Carlson, 2005) and regulatory cognitive processes. Executive functioning includes many cognitive abilities: the withholding of pre-potent behavioural responses (inhibition), recall of information and concurrent processing (executive-loaded WM), the monitoring and updating of WM representations in response to constantly changing stimuli (updating), the generation of novel verbal or non-verbal examples (verbal/design fluency), attending to specific stimuli while ignoring distracters (selective attention), moving between representational sets and/or task goals (switching/set-shifting) and planning (see Miyake et al., 2000; Pennington & Ozonoff, 1996; Singer & Bashir, 1999). Furthermore, Hayes, Gifford and Ruckstuhl (1996) suggested that EF abilities are important for novel task performance (tasks to which there are no learned automatic response patterns).

Executive function (EF) has been associated with frontal cortical brain regions (e.g. Welsh, Pennington & Groisser, 1991).

1.5.1.2. Frontal lobes / executive functions and prospective memory

The frontal lobes have been suggested to support the self-initiated processing that is required for PM tasks (McFarland and Glisky, 2009). For example, forming a strong association between a PM cue and the intention, retaining the intention during the time interval between intention formation and its execution, dividing attention over ongoing and PM task demands, monitoring for cues, and interrupting and inhibiting ongoing activities have all been found to be impaired in frontal lobe patients (Fuster, 1997; Stuss & Benson, 1984). In addition, prospective memory tasks require participants to switch between the ongoing task and PM activity. Departing from the ongoing activity which is required in PM tasks has also been argued to require executive processes i.e. breaking out from an ongoing activity (Van den Berg, Aarts, Midden & Verplanken, 2004). Moreover, McDaniel and Einstein (2000) stated that executive resources need to be allocated to a PM task in order to bring the intended action to mind periodically.

Studies employing electrophysiological and functional imaging measures have shown that PM task performance involves frontal lobe activation. For instance, Burgess et al. (2001) administered four event-based PM tasks to eight healthy adult participants in order to investigate the involvement and roles of brain structures in PM tasks. The four tasks employed a variety of ongoing and PM tasks requiring decisions to be made on the basis of shapes, colours, semantic categories and numbers of letters. Each of these tasks was administered under three conditions. The first condition was a baseline condition where no PM trials were included. In the second condition called the “expectation” condition, participants were told that there would be PM trials but no PM trials were actually shown to participants. In the third condition participants were told that PM trials might occur, and they did. This condition involved the actual execution of the PM tasks. A positron emission tomography (PET) and MRI scanning methods were used in order to investigate regional cerebral blood flow (rCBF) in order to distinguish between brain activity related to maintaining a PM intention and the manifestation or realisation of it. The results from the comparison of the baseline condition and two other conditions where PM trials were expected, showed an increase in the rCBF in the frontal pole bilaterally (especially Brodmann’s area; BA 10), right lateral prefrontal cortex (PFC), the right parietal lobe, and the precuneus bilaterally. These increases in rCBF in these areas were argued by Burgess at al. (2001) to be related to the maintenance of the prospective intention in ones mind. The authors of this study argued that it is the process of monitoring which supports the retrieval of PM that is dependent on the PFC.

Burgess, Veitch, de Lacy Costello and Shallice (2000) investigated multitasking abilities which included RM, PM and planning in a sample of 60 patients with focal cerebral lesions. On the basis of the results the authors argued that PM and planning rely strongly on processes supported by left Brodmann's areas 8, 9 and 10 and the right dorsal prefrontal cortex. Rule-breaking and task-switching was found to be related to medial and more polar parts of Brodmann's areas 8, 9 and especially 10.

A study conducted by Okuda (2007) used PET to investigate activation of the brain regions while performing time-based and event-based PM activities. The rostral prefrontal region of the brain was shown to be activated while participants were performing prospective memory tasks. More specifically, the medial frontal lobe among two other regions of the rostral prefrontal area (the right superior frontal gyrus and anterior cingulate gyrus) has been found to be more active while participants were performing time-based PM tasks compared to event-based PM tasks. Okuda (2007) concluded that these findings suggest that there are different processing demands produced by time-based and event-based PM tasks. This is in line with Einstein and McDaniel (2007) who stated that time-based tasks encourage monitoring processes, as there are no PM cues and one needs to self-initiate checking of time. This was compared to event-based PM tasks where spontaneous retrieval processes are more likely to be employed, as there are PM cues embedded in the PM task.

Little is known about the cognitive functions of the rostral prefrontal region also known as Area 10 of the brain (Burgess, Gilbert & Dumontheil, 2007; Burgess, Gilbert, Dumontheil & Simons, 2001). This large area of the brain is known to be involved in cognitive processes supporting attending self-generated/-maintained thought (stimulus-independent attending) or stimulus-orientated attending (Burgess at al., 2001; 2007). Both of these cognitive processes are very important and relevant to PM memory as stimulus-independent attending is crucial for time-based PM whereas the stimulus-orientated attending for event-based PM. Namely, time-based PM tasks rely more on self- initiation and thus are more stimulus-independent whereas the event-based PM relies more on environmental cues and thus is more relevant to stimulus-orientated attending.

A number of behavioural measures also revealed relationships between frontal functioning and PM. McDaniel, Glisky, Rubin, Guynn and Routhieaux (1999) investigated the relationship between PM and frontal functioning. They administered an event-based PM task to two groups of older adults. One group was characterised by high frontal function and the other by low on the basis of a battery of neuropsychological tests (Glisky, Polster & Routhieaux, 1995). The PM task in this study involved responding to the word *president* by pressing a specific key on a keyboard. The ongoing task involved a general knowledge test. Participants with high frontal functioning were found to be significantly better than participants with low frontal functioning on the event-based PM task. The authors argued that this provided evidence for frontal lobes involvement in event-based PM.

Martin, Kliegel and McDaniel (2003) investigated the involvement of processes which are mediated by prefrontal executive systems in different PM tasks varying in the amount of involvement of executive functions during intention formation and intention execution stages. They argued for the possibility that the amount of EF required for a PM task is dependent on the extent to which the PM task focuses on the intention formation and/or intention execution stages, as opposed to the intention retention. Namely, the more relative weight is directed towards intention formation and intention execution stages, the greater the involvement of executive processes. Unlike event-based PM tasks (which are believed to involve relatively few strategic retrieval processes), time-based PM tasks have been hypothesised to involve greater amounts of EF. Since these tasks involve self-initiated monitoring in the intention execution stage and monitoring has been reported to be controlled by prefrontal function (Shallice & Burgess, 1991, Shimamura, Janowsky & Squire, 1991).

Martin et al. (2003) used a standard clinical PM measure of event-based PM named the Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn & Baddeley, 1985), in which participants needed to remember to request a return of an item at the end of the testing session. This task was not expected to involve any strategic executive control processes in the intention execution phase, as it only involved a single event-based task which focussed on the retention and reinstantiation stages in a less demanding setting. Researchers also used standard laboratory event- and time-based PM measures (e.g. Einstein et al., 1997; Kliegel et al., 2001), as they would likely involve moderate involvement of EF, as these paradigms focus on the intention execution in a demanding task setting. The last PM task was a complex PM task developed on the basis of a task used by Kliegel et al. (2000) and focused on intention formation and intention execution stages in a demanding task setting. This multitask PM paradigm (MTPM) involved a mixture of six time- and event-based PM activities, which required planning during the intention formation phase and was argued by the researchers to rely on the greatest amount of prefrontal functioning.

Three standard neuropsychological tests were used to measure EF, these were the Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay & Curtiss, 1993), a colour-word version of the Stroop task (Stroop, 1935), and the Tower of London (TOL; Morris, Evenden, Shakian & Robbins, 1987). These EF measures allowed the researchers to measure specific aspects of frontal functioning which are theoretically related to PM performance e.g. planning, inhibition, cognitive and response flexibility, and monitoring. The results from the principal components analysis with z-scores from all EF tests showed that there was a single executive factor which represented common variance of the three tests.

Martin et al.'s (2003) first goal was to investigate further the extent of the involvement of prefrontal executive processes in the four standard PM tasks employed in this study. They were also interested in investigating whether age related differences in different PM tasks can be explained by individual differences in EF. They employed forty young and 40 old adults, as frontal functioning has been argued to decline with age (e.g. Schretlen, Pearlson, Anthony, Aylward, Augustine, Davis & Barta, 2000; Wecker, Kramer, Wisniewski, Delis & Kaplan, 2000). The results showed age related performance differences on the experimental time- and event-based PM tasks, and on the complex PM measure only. On the three frontal/EF measures, age related differences were evidenced, with age related differences increasing as the involvement of frontal/executive functions in the four different PM tasks increased. Also a series of corrections employing the four PM measures and EF factor scores for young and old adults computed separately, indicated that the laboratory time- and event-based PM tasks as well as the MTPM task correlated significantly with EF in older adults, but not in younger adults.

Additional analysis involving a stepwise regression revealed that individual differences in EF explain a large amount of variance of PM performance on the majority of the PM tasks used by Martin et al. (2003), with the exception of the RBMT task. After addition of age into the regression, the researchers found that there was no significant increase in explained variance in performance in the laboratory event- and time-based PM tasks. Interestingly, in the MTPM task it was not only the EF measures that explained variance in PM, but also age and nonexecutive measures such as RM and health. These results showed no significant effects of group membership on any of the four PM tasks. Also post hoc tests showed no significant mean differences in the RBMT, but there were similar performances in the young adults and old adults with high EF compared to old participants with low EF in the event- and time-based experimental measures. There were also significant differences between all three groups in the MTPM task. The authors argued that the results demonstrated a clear relationship between the extent to which frontal/executive functions are involved in PM task performance, with EF predicting the PM performance on the experimental time- and event-based PM tasks. In the most complex measure of PM (MTPM), both EF and age were good predictors of PM performance. In general, it was argued that frontal/executive functions are related to PM performance in a range of PM paradigms.

McFarland and Glisky (2009) further supported the claim that the frontal lobe is involved in PM task performance. They used a laboratory time-based PM task on a group of 32 younger and 32 older adults. They divided their older participants ortoganally into four groups based on composite measures of frontal lobe and medial temporal lobe function. In addition, this study also investigated age effects with each of the four groups of older adults being compared to a control group of younger adults. The results showed that older participants who were in the high frontal lobe group performed significantly better on the time-based PM task compared to low frontal lobe group. It was also found that older adults from the high medial temporal lobe group were better than participants from the low medial temporal lobe group when it came to PM performance, but only if they were also high in frontal lobe functioning. In addition, frontal lobe functioning was found to predict the quality of plans which participants generated in order to assist PM performance, patterns of time monitoring and accuracy of time estimation. Medial temporal lobe was not found to predict any of these. Similarly to the PM performance results, the results from older adults with high frontal lobe function across all of these measures were similar to these of younger adults. The authors concluded that it is frontal functioning which determined PM performance rather than age alone.

1.5.2. Working memory

1.5.2.1. Working memory definition

Working memory has been conceptualised as the updating component of EF (e.g. Miyake, Friedman, Emerson, Witzki, Howerter &Wager, 2000). It is a multi-component, limited-capacity system responsible for the temporary storage and processing (i.e. manipulation, integration and maintenance) of limited amounts of information (Baddeley, 1997). Working memory consists of two modality-specific slave systems, namely, the phonological loop which is involved in the storage and manipulation of phonologically-based information and the visuo-spatial sketchpad involved in the storage and manipulation of visual and spatial information (Baddeley, 1986; Baddeley & Hitch, 1974). There is also the central executive (CE) which is a controlling attentional system playing a supervisory role over the slave systems. The function of the CE is related to how, where and when to allocate resources, bind information, shift between tasks or retrieval strategies and inhibit responses. The CE has been thus claimed to be involved in the allocation of resources needed to manage and maintain information while temporal performance of other activities takes place (Baddeley, 1986; 2002). There is also one modality-free slave system constituting a part of WM, the episodic buffer which is a multi-dimensional storage, integrating information from different components of WM (Baddeley, 2000; 2007).

1.5.2.2. Working memory and prospective memory

Prospective memory has been suggested to be heavily dependent on WM (Einstein, McDaniel, Manzi, Cochran & Baker, 2000). This, as Einstein et al. (2000) explained, is because PM tasks require active or nonstrategic maintenance of the intended action in WM over the time interval between formation and execution of the intention, while also performing an ongoing task. Furthermore, Smith, Persyn and Butler (2011) found a positive relationship between WM span and PM. This experiment with a large sample of participants (n = 413) used a symmetry span task as a measure of WM span. The PM task employed an ongoing lexical decision task and an event-based PM task, where participants were required to press the F1 key when syllables “per” and “low” appeared. High and low WM span groups were created on the basis of span scores (top and bottom 25% of performers). The results showed that participants in the high WM span group were more likely to perform well on the PM task whereas, the low WM group performed more poorly.

It has been claimed by various researchers that the ongoing task can negatively affect PM performance as it draws on the same limited WM central executive resources (Einstein et al., 1997; Kliegel, McDaniel & Einstein, 2008; Marsh & Hicks, 1998). It is possible that the ongoing task draws away WM resources needed for PM task performance, causing interference effects. The interaction between ongoing tasks, which require WM, and PM tasks have been investigated by Basso, Ferrari and Palladino (2010). They investigated whether PM and WM share resources or whether they are distinct processes. To achieve this, the authors conducted three experiments employing a verbal task which allowed a manipulation of cognitive demand, related to event-based PM and WM tasks. This manipulation effectively varied the amounts of resources available for each of the memory processes (PM and WM). They also used transcranial magnetic stimulation (TMS) in order to investigate the involvement of frontal areas of the brain in the performance of PM and WM tasks. The event-based PM task involved responding to cue words. The number of cue words was manipulated in order to vary the level of PM difficulty. There were two ongoing tasks employed in this study, one involved an updating WM task (Palladino & Jarrold, 2008), which created either high or medium WM demands and the other involved a lexical decision task which created low WM demands. The results of both experiments showed that higher PM demand impacted negatively on WM performance but only when the WM ongoing task involved higher loads. However, the PM load had an effect on PM performance regardless of WM load differences. The last experiment applied a single pulse TMS to right and left dorsal frontal cortices while participants were engaged in the PM/WM tasks. The results showed that regardless of whether the stimulation was applied to right or left dorsal frontal cortices, it resulted in more PM failures. However, the TMS simulation affected the WM task only marginally. On the basis of their results Basso et al. (2010) argued that even though it seems that PM and WM are different processes, they are likely to share resources but only in tasks involving high demands. Namely, PM tasks have been argued to be dependent on WM resources at high demand. It was also shown that dorsolateral prefrontal cortex was activated bilaterally during PM tasks.

Van den Berg, Aarts, Midden and Verplanken (2004) have stated that tasks which are difficult are more likely to be affected by executive load compared to tasks that are easy and well supported by the environment. This is in line with the multiprocess theory of PM (McDaniel & Einstein, 2000) which states that more difficult PM tasks (e.g. with non-focal PM targets) may require more monitoring processes compared to easier PM tasks (focal) and is likely to rely on spontaneous retrieval. More difficult PM tasks relying on monitoring processes are more taxing on WM in comparison to tasks that encourage spontaneous retrieval, and may result in worse PM performance compared to easier PM tasks.

Marsh, Hancock and Hicks (2002) conducted a series of experiments manipulating the WM load of the ongoing task and found that the PM performance was reduced when the ongoing task engaged more WM resources. They concluded that PM tasks are affected by WM load because PM tasks involve the coordination of both the ongoing task and the PM task and that this process involves executive control (at least to certain degree). There are a number of studies which have demonstrated the negative effect of high WM load on PM performance especially if the CE is affected (e.g. Einstein et al., 1997; Marsh & Hicks, 1998).

Khan, Narendra and Dixit (2008) investigated what effect low and high cognitive load has on time-based PM tasks. The results showed that PM performance was significantly lower in the high cognitive load condition compared to the low cognitive condition. The authors proposed that this occurred due to dividing attentional resources between the ongoing task, monitoring time and self-initiating the PM response at the required times. They suggested that monitoring of time is dependent on the limited resource of attentional capacity and thus, cognitively demanding tasks will have a negative effect on PM performance.

1.5.3. Theory of action control including the supervisory attentional system

1.5.3.1. Definition of theory of action control including the supervisory attentional system

The Norman and Shallice (1986) theory of action control is a general theory which explains how action is controlled. It proposes that willed and automatic actions are controlled at different levels and the extent to which these actions are controlled depends on the degree of task difficulty and complexity. Actions are controlled by two mechanisms, contention scheduling and a supervisory attentional system. Only novel or complex tasks (also these involving planning) require cognitive resources and these resources are provided by the supervisory attentional system (SAS), which enables selection of the desired response. The SAS mediates attention, which in turn can control the activation or inhibition of values of behavioural schemas. In other words the SAS organises, coordinates and monitors schemas, which enable the achievement of novel and complex tasks. This is achieved with attention and awareness through a general-purpose planning component which is able to adapt to novel domains. Tasks which are habitual, well-learned or involving automatic response can be performed by the means of a contention scheduling mechanism alone, without involvement of the SAS. During this low level of control mechanism, an appropriate response is selected by lateral inhibition of competing response sequences (schemas). Only in situations where a deviation from routine is needed, the SAS will influence behaviour by biasing the contention scheduling process.

The SAS component of the theory of action control has been proposed by Baddeley (1986) to be a candidate for the CE component of WM model and similar to the CE, it controls attention. In addition, the SAS may also be related to EF as it has been claimed by Hayes et al. (1996) that

EF abilities are important for novel tasks and SAS has been identified to be responsible for novel tasks. The next section describes the relevance of SAS to PM.

1.5.3.2. Theory of action control and prospective memory

Norman and Shallice's (1986) theory of action control can be used to explain why high cognitive load impacts negatively on PM performance (e.g. Khan et al., 2008). Monitoring theories of PM (e.g. the preparatory attentional and memory theory (PAM; Smith, 2003) and multinomial theory (Smith & Bayen, 2004) claim that PM memory is dependent on monitoring processes. Moreover, as Smith (2003) stated monitoring processes improve PM performance. Monitoring processes have been argued to be controlled by an executive attentional system such as the SAS, which directs attentional resources. Indeed, Burgess and Shallice (1997) proposed that PM performance is mediated by the SAS and that this form of memory is a voluntary strategic process. They argued that the SAS is involved in monitoring for PM cues and executive resources are necessary for this process. Thus, the involvement of the SAS is especially crucial in PM tasks, which rely strongly on monitoring. In addition, because executive resources are necessary for monitoring processes, ongoing tasks involving high cognitive load may draw on the same limited resources resulting in decrease of PM performance. Since, as previously stated, it has been proposed that the SAS component is similar to the CE component of WM model (Baddeley, 1986). Therefore, as the monitoring of PM performance requires SAS; tasks that involve high a cognitive load will reduce PM performance, especially when these tasks also involve CE (e.g. Marsh and Hicks, 1998).

The contention scheduling system described in the theory of action control could also be related to automatic processes involved in PM. The spontaneous retrieval theory of PM claimed that spontaneous retrieval of PM is relatively non-demanding on attentional and processing resources and does not require monitoring (Einstein & McDaniel, 1996; Guynn, McDaniel & Einstein, 2001; McDaniel & Einstein, 2000; McDaniel et al., 2004). In addition, this theory states that the process of retrieving of PM intentions is much more automatic. The contention scheduling mechanism identified by the SAS model (Norman and Shallice, 1986) has been claimed to be responsible for automatic responses by selection among well-learnt competing schemas. Thus, contention scheduling could be argued to be responsible for PM tasks that rely on spontaneous retrieval processes as well as habitual PM. However, the SAS is still likely to be required for breaking out of the ongoing task.

Finally, the SAS executive system is also responsible for interruption to the ongoing activity and shifting attention to the intended action at the appropriate moment (i.e. when the PM cue appears; Einstein et al., 2005). This feature of the SAS will have an influence on PM tasks, as inhibition and switching have been found to be closely related to PM performance (e.g. Altgassen et al., 2014; Gonneaud, Kalpouzos, Bon, Viader, Eustache & Desgranges, 2011; Schnitzspan, Stahl, Zeintl, Kaller & Kliegel, 2013). Furthermore, as the SAS deals with task novelty by regulating the mechanism of contention scheduling by additional activation or inhibition of specific schemas, it is highly relevant to inhibition and switching processes.

1.5.4. Inhibition, switching and prospective memory

Prospective memory tasks require one to inhibit performance on the ongoing task in order to switch to the performance of PM task. There have been a number of studies which have showed that PM performance can be predicted on the basis of EF/WM measures in children. For instance, Mahy and Moses (2011) used digit span task to measure WM and found that it predicted event-based PM performance of children between the ages of four and six, even though they controlled for age and inhibition measured by the day/night task. Ward, Shum, McKinlay, Baker-Tweney and Wallace (2005) also found that PM performance in tasks which employed high ongoing task demands (presenting items in a lexical decision task for a shorter amount of time), correlated with WM and inhibition. Mahy, Moses and Kliegel (2014) found that on the basis of inhibition abilities, it was possible to explain differences on event-based PM tasks employing salient and non-salient cues in four and five year olds. This study has also shown that individual differences in inhibition were responsible for age related difference in PM performance. Moreover, differences in event-based PM performance of a group of children who were between the ages of 8 and 9 and a group of children between the ages of 12 and 13 were accounted for by performance on a range of executive control measures in a study conducted by Shum, Cross, Ford and Ownsworth (2008).

Altgassen et al. (2014) conducted a study as a part of which they investigated whether updating, inhibition, and switching processes can predict PM performance of adolescents and young adults. They employed 42 adolescents between the ages of 13 and 14 years old and 41 young adults with age range of 19-20. The ongoing task involved making a comparison between the number of vowels contained in pairs words that were made up of nouns. The PM task used in this study had an event-based PM nature, employing a non-focal PM cue in order to create stronger demands on executive control processes. Altgassen et al. measured updating abilities in

WM using the letter memory task, similar to that used by Miyake et al. (2000). Likewise, the inhibition and switching were also assessed in a similar way to that of Miyake and colleagues (2000). Inhibition was assessed using the antisaccade task whereas switching abilities were measured on the basis of the colour-shape task. This study found that adolescents performed significantly less well when compared to young adults on the PM and ongoing tasks as well as measures of switching, inhibition and updating. However, only switching significantly predicted the PM performance of adolescents even when ongoing task performance, verbal and nonverbal abilities were controlled for. None of the executive control measures predicted PM performance in adults. Altgassen and colleagues interpreted the findings in terms of the development of self-regulation in adolescents, but they argued that the specific pattern of processes underpinning PM performance may not be only dependent on specific age group but also on the use of a specific PM task and its reliance on different control processes (Kliegel et al., 2011 cited in Altgassen et al., 2014).

In line with Altgassen et al.'s (2014) opinion that the type of PM task will affect the involvement of different control processes, Bisiacchi et al. (2009) found that different PM paradigms (i.e. dual-task and task-switching) resulted in different processing and neurophysiological dynamics, related to attentional resources and cognitive control. They tested seventeen young adults (between the ages of 18 and 29) on a standard experimental event-based PM task. The ongoing task required participants to decide whether the second and fourth letters of a letter string were the same. The PM task involved responding to the letter "B" appearing in either of these positions. There were also distracter trials which included the letter "B" but in other positions (e.g. first) in order to avoid PM decisions being made on the basis of perceptual characteristics of letter strings. In the task-switching condition participants were told to respond to the PM cue when it appeared, without a response being required in the ongoing task. This first condition include two production rules, which stopped the performance of the ongoing task in order to respond to the PM task or the other way round (i.e. do not respond to the ongoing task - respond to the PM task). In the dual-task condition participants first responded to the ongoing task when they saw the PM cue and then switched to the PM task when they saw a PM cue. Bisiacchi and colleagues recorded accuracy, RT and electroencephalogram (EEG) data. The results showed that participants in the task-switching condition took longer to respond to the PM cues compared to participants in the dual-task condition. The authors argued that the shorter RTs of PM responses in the dual-tasks condition could be due to loading of "response programs" related to both the ongoing and PM tasks at the same time (once the PM cue was encountered). However, in the task-switching condition participants had to suppress the tendency to respond to the ongoing task demands. This was also argued to explain higher PM accuracy in the dual-task condition in comparison to the task-switching condition. They argued that the results supported earlier claims that task-switching involves additional cognitive control and response tendency suppression (Dreher & Grafman, 2003; cited in Bisiacchi et al., 2009). Cognitive control has been claimed to be especially necessary in circumstances requiring rapid change of response associations and when dominant response tendencies need to be suppressed immediately. This was suggested to be caused by the conflict between the ongoing and PM tasks.

On the basis of the results Bisiacchi and colleagues reasoned that these two PM task paradigms involved different cognitive processes. It was argued that task-switching involves inhibition whereas it is not necessary for the dual-task paradigm. The results from EEG were argued to show that both dual-task and task-switching PM conditions supported studies showing activation of rostral prefrontal cortex (e.g. Okuda, Fujii, Ohtake, Tsukiura, Yamadori, Frith, 2007) and more generally the involvement of frontal networks during PM task performance (e.g. Dreher & Grafman, 2003; cited in Bisiacchi et al., 2009). The results were also argued to possibly support the task inhibition process found using the behavioural data in the task-switching condition. The authors theorised that the two paradigms used did not create any differences in terms of cue detection and retrieval of PM action from long-term memory. However, they suggested that the task-switching paradigm may resemble a real life PM task where one needs to press the brakes at a passenger crossing when the traffic light changes to red. On the other hand, they suggested that the dual-task paradigm is more related to a real life task involving calling the doctor after 11am which is less constrained.

Another study arguing for involvement of inhibition in PM is a case study of J.B. conducted by Cockburn (1995). J.B.'s frontal lobe was infracted bilaterally which resulted in impairments in planning, initiation and inhibition of ongoing behaviour. Nevertheless, J.B.'s RM was intact. This study used nine time-based (three were follow-up re-assessment PM measures) and five event-based PM tasks which could all be categorised as every-day PM tasks. Overall, J.B. performed correctly on all event-based PM tasks and on five out of nine time-based PM tasks (although one of the time-based PM tasks could be argued to be an event-based task). It seemed that J.B.'s difficulties with PM tasks were specific, failing on PM tasks which involved high levels of self-initiated interruption of the ongoing activity. J.B.'s performance was only impaired on time-based tasks which involved stopping the ongoing tasks completely or switching to another ongoing task, without finishing the first ongoing task. J.B. was able to recall that she was supposed to stop performing the ongoing tasks after certain numbers of minutes at the end of the tasks, indicating intact RM. She was also reported to check the clock which eliminated the possibility that she was unaware of the time.

J.B. was able to break out from the ongoing activity in one time-based activity, by inhibiting further filler task responses even though the items of this filler tasks did not finish. In this task J.B. was instructed (before the task began) that she would need to stop performing the ongoing task after one minute, when the experimenter tells her that the one minute has elapsed. Whilst this task was classed as a time-based PM task, it could be argued to be an event-based PM task, as interruption of the ongoing task needed to be performed when the experimenter informed the participant that the time was up, which itself was an event. Successful completion of this task could be as a result of there being no or minimal involvement of self-initiated processes which in turn means little EF involvement.

On the basis of these results, Cockburn argued that there may be two types of time-based PM tasks, one which requires interruption of the ongoing task and another which complements the ongoing task. Furthermore, Cockburn suggested that these time-based PM tasks which require interruption of an ongoing task may require the highest levels of self-initiation. Errors performed by J.B. were argued to be caused by failure of initiation, which was suggested by Cockburn to be related to problems with attentional control rather than problems with memory. Cockburn argued that J.B.'s performance on the PM tasks resembled deficiencies related to the SAS model (Norman & Shallice, 1986). Namely, Shallice (1982; cited in Cockburn, 1995) proposed that SAS is responsible for prioritisation and control of action schemas which compete for attentional resources. Thus, it was claimed that problems with SAS will resemble problems with formation, initiation and modification of plans. In addition, Shallice reasoned that the stronger the environmental trigger, the more likely that the action will be selected. Cockburn showed that the selective PM problems found in J.B. (whose frontal lobe was infracted bilaterally) supported the claims presented by Shallice. Namely, J.B.'s PM problems were evident in tasks which involved ongoing activities that delivered a stronger triggering compared to the PM tasks. On the contrary, J.B. performed successfully PM tasks in which target context was provided by an external event where she needed to recognise it when it occurred rather than search for it. These types of tasks were argued by Cockburn to require less attentional control as responses could be driven by the data.

The results from this study were argued to indicate that J.B.'s PM failures were related to problems with activation of target context as a trigger for activation of PM intention. Cockburn explained that ongoing tasks which are more influential than the encoded intended action result in problems with recognition of context related to retrieval. In tasks where interruption of the ongoing task requires its termination, the target context is not activated enough in order to override the level generated by the ongoing task. On the contrary, in tasks involving PM activities that can be performed in parallel to the ongoing task, the target context is activated leading to triggering and execution of the PM intention.

Cockburn suggested that because time- and event-based PM tasks involve self-initiation and prioritising of the suitable response, it is possible that J.B.'s PM failures were also based on problems with prioritisation and not just self-initiation. The author argued that it is possible that J.B.'s inadequate prioritisation was unable to override the strong draw to complete the ongoing task. It was also suggested by the researcher that even though J.B.'s PM problems appear to be related to self-initiation problems, it is possible that these problems are related to difficulties with interruption of the ongoing activities. This reasoning was argued to be in line with J.B.'s inhibition errors found on a modified version of the WCST (Nelson, 1976; a task sensitive to frontal lobe deficits) which required continuous attention, monitoring of performance and periodic inhibition of previously established pattern of action. Finally, Cockburn concluded that J.B.'s performance on the PM tasks is related to impaired executive functioning rather than to memory problems per se.

Recent studies also showed that PM tasks involve strongly EF such as inhibition or shifting. For instance a study conducted by Schnitzspan et al. (2013) investigated PM and EF in 175 young and 110 older adults. They used measures of PM, shifting, inhibition, WM, updating, and speed and found that inhibition and shifting strongly predicted PM. They also found age related differences in PM, shifting, inhibition and updating. Shifting and inhibition abilities also accounted for age differences in PM. However, updating was not found to be related to PM performance in either of the participant groups. Overall, EF was shown to increase the extent to which the variance in PM was explained and decreased the effect of speed. Nevertheless, this study suggests that WM was not a good predictor of PM performance. However, there is more evidence which argues for the dependence of PM on WM (e.g. Smith, 2003; Einstein et al, 2000; Smith et al, 2011). Schnitzspan and colleagues argued that controlled attention differences can explain age related differences in PM and that inhibition and shifting are important mechanisms underpinning PM of adults, beyond WM and speed. The differences in controlled attention could again be related to SAS as it is responsible for attention allocation.

Gonneaud et al. (2011) investigated the relationships between event- and time-based PM measures and a wide range of cognitive functions, including executive functions, processing speed, sustained attention, retrospective episodic memory, metamemory, and binding in healthy adults. This study found that regardless of the conditions, PM was linked to inhibition and processing speed. Furthermore, it was found that event-based PM was strongly reliant on binding and retrospective episodic memory and, to a lesser extent, on shifting, while time-based PM depended largely on inhibition.

1.6. Summary

There are two main types of PM which can be distinguished, namely, time- and event-based PM types. Even though both of these types of PM involve prospective remembering, the memory retrieval involved in each PM type is underpinned by different types of cues. In the time-based PM, it is the time which acts as a cue reminding individuals to perform the intended action. In the event-based PM the cue is not related to time but takes the form of a distinct feature in the environment which brings about the PM activity associated with it e.g. when seeing a pharmacy sign an individual remembers to pick up medication for his/her grandmother.

There are many theories of PM, but the main debate in the field of PM is related to the cognitive processes underpinning successful retrieval of PM. The major theories of PM debate whether PM is based on automatic spontaneous retrieval processes (e.g. Einstein & McDaniel, 1996; Guynn et al., 2001; McDaniel & Einstein, 2000; McDaniel et al., 2004) or whether monitoring / preparatory attentional processes are required for successful PM retrieval (McDaniel & Einstein, 2007). Even though the debate initially started off with an argument about which of these two processes underpin PM, it has been developed further by the multiprocess theory (McDaniel & Einstein, 2010) which assumes that it is possible that both of these processes can underpin PM under different circumstances. Additionally, the multiprocess theory tries to identify conditions under which each type of processing occurs. A number of factors have been identified to have an effect on the type of processing which is likely to underpin PM tasks. One factor is related to the perceived difficulty of the PM task. It has been argued that tasks which are perceived as more difficult lead to greater engagement in monitoring processes. Another factor is related to the type of PM cue and its relationship to the ongoing task. Namely, focal PM tasks have been argued to be more likely to encourage automatic spontaneous retrieval and non-focal PM tasks to be more likely to trigger monitoring processes.

Prospective memory has been shown to be strongly dependent on frontal functioning. Studies have shown that EF as a general concept has a strong influence on PM performance. In addition, studies have shown that high cognitive load impacts negatively on PM performance. It was argued that this could be due to problems with the allocation of attention (SAS; Norman & Shallice, 1986), insufficient executive resources for monitoring processes or self-initiation. Evidence has been also provided that WM abilities are related to PM performance. Likewise, inhibition and switching have been shown to predict PM performance. It is also evident throughout this chapter that the theory of action control and especially its SAS component is involved in PM and can be used to explain results from PM tasks.

Chapter 2: Dyslexia

Despite the many scientific theories to explain dyslexia, the causes of developmental dyslexia are yet unknown (see Snowling, 2000). The difficulty in establishing the causes of dyslexia may be related to the difficulty in establishing a clear cut account of deficits that constitute dyslexia (Ramus, 2004). The most predominant theories and deficits related to dyslexia are summarised in this chapter in order to provide a comprehensive summary of the dyslexia literature. These include the body of evidence suggesting problems with phonological processing in dyslexia (e.g. Vellutino, 1979; Frith, 1985; Stanovich, 1988a; Snowling, 1995), naming speed deficit (e.g. Denckla & Rudel, 1976; Bowers & Wolf, 1993), double-deficit hypothesis (Wolf & Bowers, 1999), magnocellular theory (Stein & Walsh, 1997), temporal processing theory (e.g. Tallal & Piercy, 1973), dyslexia automatisation deficit (Nicolson & Fawcett, 1990), cerebellar deficit theory (Nicolson & Fawcett, 1990; Nicolson et al., 2001) and EF deficits in dyslexia including WM, CE, SAS, inhibition and switching (e.g. Smith-Spark et al., 2003; Smith-Spark & Fisk, Varvara et al., 2014). Nevertheless, only some of these deficits and theories characterising dyslexia are pertinent to processes and theories of PM when establishing the rationale for PM deficits in dyslexia, but these are described in the next chapter (Chapter 3) which provides a synthesis of the two bodies of evidence (PM and dyslexia).

2.1. Definition

Developmental dyslexia has been recognised for over a hundred years. In 1896 the term developmental dyslexia began to gain its shape in relation to word blindness from a medical account (Morgan, 1896). Snowling (2000) states that the worldwide population affected by dyslexia is large and varies somewhere between 3 and 17.5% (Pennington, Gilger, Pauls, Smith, Smith & DeFries, 1991; Lyon, 1996; Shaywitz, 1998). However, many argue for the lower end of the estimate. For example, Rutter and Yule (1975) analysed a cohort of UK children whose school achievements were poor and found that about 4 % of these children showed delay in development of reading skills. Traditionally, developmental dyslexia is defined as a discrepancy between an individual's reading ability and intelligence despite normal opportunities to learn to read (Demonet, Taylor & Chaix, 2004; Ramus, 2003; Snowling, 2000; Vellutino, 1979). Therefore, the common denominator for all individuals with dyslexia is the problem with reading (Doyle, 1996). The diagnosis of dyslexia is usually based on a battery of standardised psychometric tests which allow one to check whether there is a discrepancy between an individual's actual literacy skills and the literacy abilities expected for his/her chronological age and IQ. Individuals with IQ within the normal range (85-115) and whose literacy skills do not match the abilities expected for their chronological age would be considered to have dyslexia. However, individuals with poor literacy skills accompanied by low IQ (lower than one SD from the mean; lower than 80) would be considered to be “generally backward readers” (Snowling, 2000).

2.2. Deficits and theories

2.2.1. Phonological deficits

A number of early studies investigated phonological processing symptoms that characterise developmental dyslexia in children. For example, a study investigating differences in boys with and without dyslexia found that those with dyslexia started to speak later than those without dyslexia, and displayed problems with articulation and spelling (Naidoo, 1972). Vellutino (1979) suggested that dyslexia is a language disorder and proposed the verbal deficit hypothesis which claimed that individuals with dyslexia have verbal coding deficits. A wide body of research has strongly suggested that individuals with dyslexia display deficits when it comes to speech processing in relation to written language (Thambirajah, 2010; Snowling, 1995; Wagner & Torgensen, 1987; Snowling, 2000). In other words this is a problem at the level of phonological representation. The ability to read fluently is based upon the ability to store appropriate representations related to the spelling of those words (Vellutino, Fletcher, Snowling & Scanlon, 2004). Reading involves phonological coding and tasks such as processing information in WM, storing printed words and retrieving words as distinct representations (Stanovich & Siegel, 1994; Wagner & Torgesen, 1987; Torgesen, Wagner, Rashotte, Burgess & Hecht, 1997); these are argued to be sensitive to deficits in phonological coding.

In addition, in order to develop reading and spelling skills a child needs strong phonological awareness. Phonological awareness requires individuals to have a good knowledge of the sounds that are used to form the structure of language (Stanovich, 1988a, 1988b; Catts, Adlof, Hogan & Weismer, 2005). Children need phonological awareness in order to be able to recognize and use rhyme (i.e. bike rhymes with like), break words into syllables, blend phonemes into syllables and words (i.e. blending /c/ - /u/ - /p/ to make cup), identify the beginning and ending sounds in a syllable and see smaller words within larger words (i.e. “child” in “children”). They should also be able to identify and manipulate phonemes (i.e. change rug to mug). Phonological awareness can be further broken down into different skills that are argued to be on a gradient of difficulty (McBride-Chang, 2004). The easiest skill is syllabic skills, which consists of isolating words or syllables. This is followed by the harder skill of recognising intermediate units of words (onset and rimes). This requires individuals to be able to split words of one syllable into onsets (initial consonant or cluster of consonants in the word) and rime (the vowel and consonant that follows the onset). An example is the word ball, where /b/ is the onset and /all/is the rime. The hardest skill to acquire is phonemic knowledge, which is the ability to recognise that words are made up of the smallest units of sound (e.g. that the word frog is made up of; /f/ /r/ /o/ /g/).

Reduced phonological awareness in children has been found to be related to poor reading and spelling skills (Snowling, 1981, 1995; Stanovich, 1988a, 1988b; Stanovich & Siegel, 1994; Lervåg, Bråten & Hulme, 2009). It is also widely recognised that individuals whose phonological awareness is poor at the phonemic level, will be at a disadvantage in the acquisition of the alphabetic principle (an understanding that letters and letter patterns represent the sounds of spoken language) and this is central to the phonological deficit hypothesis (Frith, 1985; Snowling, 1995).

2.2.1.1. Phonological deficit hypothesis

The phonological deficit hypothesis suggested that individuals with dyslexia have a limited awareness (poorly coded or degraded phonological representation) of the different sound structures of language that can be used to build or manipulate words (Szenkovits & Ramus, 2005; Goswami, 2002). This theory derived from the verbal deficit hypothesis (Vellutino, 1979) and led to the traditional definition of developmental dyslexia which claims that developmental dyslexia is underlined by problems with phonology (Frith, 1985; Snowling, 1995). The phonological deficit hypothesis has been also the principal framework for explaining many of the deficits and has provided the foundations for many of the positive interventions developed for individuals with dyslexia (e.g. Stanovich, 1988b; Bradley & Bryant, 1978; Vellutino, 1979; Wager & Torgesen, 1987; Vellutino & Scanlon, 1987; Vellutino et al., 2004).

The phonological deficit hypothesis is based on a number of studies which found that children with dyslexia perform worse compared to children without dyslexia on tasks involving phonological awareness, verbal learning, rapid naming and coding of letters and sounds (e.g. Vellutino & Scanlon, 1987; Wagner & Torgesen, 1987). This theory has been widely recognised and researched (e.g. Ramus et al., 2003; Ackerman & Dykman, 1993; Wolf &

Bowers, 2000). In addition, Foy and Mann (2003) investigated reading ability development in pre-school children and showed that phoneme awareness (which is the ability to hear, identify and manipulate the smallest units of sound / phonemes) was the best predictor of reading skill development. Strong support evidence for the phonological deficit hypothesis playing a key role in reading and spelling has emerged from intervention studies. An example of one such intervention study was a study conducted by Castle, Riach and Nicholson (1994). They revealed that providing specific phonemic awareness training twice a week for the course of ten weeks resulted in significantly better reading and spelling scores of five years old children, when compared to children who did not participate in the training. There is also extensive evidence that alphabetic knowledge in pre-readers' is a good predictor of later reading success (e.g. Ehri, 1987; Roberts & McDougall, 2003). Roberts and McDougall (2003) found that in the first year of school, there was a significant correlation between understanding the sound structure of words and letter knowledge.

Gathercole and Baddeley (1990) found deficits in the phonological storage component of WM, in children with disordered language development. They found that children with disordered language development performed more poorly in the repetition of abstract words, single words and concrete words. Gathercole and Baddeley also found deficits in the ability to recall a list of spoken words. Their study ruled out any possible difficulties with producing verbal output, by asking participants to respond to the task, by pointing to pictures. In addition, Mann (1984) found that the phonological memory scores of children who are starting school are significantly related to reading abilities attained (when measured at regular intervals) during the following year.

There is a large body of research and intervention studies which supports the phonological deficit hypothesis as the main causal agent of dyslexia (e.g. Stanovich & Siegel, 1994) and that these deficits continue into adulthood (e.g. Bruck, 1992). However, there have been divergent views that have disagreed with this traditional point of view, with many postulating that phonological processing is not the primary cause of reading difficulties (e.g. Castles & Coltheart, 2004). The phonological deficit hypothesis was argued to be too general, as it did not account for dyslexic individuals who were highly articulate, but still displayed specific reading difficulties. Research has also highlighted that some dyslexic individuals appear to have no deficits on phonological tasks (e.g. De Luca, Burani, Paizi, Spinelli & Zoccolotti, 2010). Furthermore, according to Snowling (2000), findings of deficits in some, but not all verbal domains are not in line with the phonological deficit hypothesis. Nevertheless, the phonological deficit hypothesis argues that dyslexia is domain-specific to phonological encoding and as such, does not involve wider cognitive domains.

2.2.2. Naming speed deficit

Further deficits in developmental dyslexia have been found in relation to the speed of processing for all types of stimuli, even for those which are unlikely to be caused by sensory delay (slow processing of sensory information). Denckla and Rudel (1976) used the Rapid Automatised Naming (RAN task) to assess rapid naming of pictures, colours or alpha-numeric stimuli. This study demonstrated that children with dyslexia had speed deficits when naming these stimuli. Wolf (e.g. Bowers & Wolf, 1993; Wolf & Bowers, 1999) stated that the RAN task investigates the repeated and speeded access to visual-phonological associations needed for reading. In addition, Wolf reasoned that rapid naming and fluent reading are both based on attention and perceptual processes which have to be well timed. These processes allow matching of visual representations to phonological codes, and Wolf argued that rapid naming is only partly a phonological process. Other researchers would strongly argue that rapid naming is a phonological process (e.g. Wagner & Torgeson, 1987). According to Wolf naming speed deficits can be thought to be underpinned by a general problem in dyslexia relating to the processing sequences of brief and rapid information. Studies showing naming speed deficits in individuals with dyslexia (e.g. Denckla & Rudel, 1976; Bowers & Wolf, 1993) were the foundation for the double deficit hypothesis.

2.2.2.1. Double-deficit hypothesis

A large body of dyslexia research has identified a deficit in the speed of processing of visual stimuli (e.g. Denckla & Rudel, 1976; Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993; McBride-Chang & Manis, 1996; Wolf & Bowers, 1999). This evidence, related to a visual stimuli processing speed deficit, combined with the phonological deficit theory was the foundation for Wolf and Bowers’ (1999) hypothesis of a double-deficit, that they believed accounted for problems in reading in individuals with dyslexia. Wolf and Bowers suggested that an individual with dyslexia can either have a problem with phonological processing (in line with phonological deficit hypothesis) or a processing speed deficit (e.g. slow naming speed). They have also suggested that these two distinct deficits can coexist; that a person with dyslexia can have both phonological and processing speed deficits at the same time (hence the double-deficit hypothesis).

Van den Bos (1998) found that dyslexic children have a deficit of both phonological awareness and processing speed, helping to pave the way for the double-deficit hypothesis. There is also a large body of evidence showing that dyslexic children are slower in naming letters and digits compared to children without dyslexia (e.g. Denckla & Rudel, 1976; Bowers & Wolf, 1993; and Snyder & Downey, 1995). This “slowness” in naming speed was found, even in a task which did not involve phonological components and this has led researchers to believe that processing speed deficits are independent from phonological deficits (Denckla & Rudel, 1976). Nicolson and Fawcett (1994) provided evidence showing that the two deficits identified in the double-deficit hypothesis (speed of processing and phonological) are in fact separate deficits independent of each other. The authors found a processing speed deficit even after removal of the phonological component of the task. This was achieved by the use of auditory tones and visual flashes as stimuli to which participants had to respond. These findings show that deficits in dyslexia are not, as was originally thought, limited to phonological processing. McCrory, Mechelli, Frith and Price (2005) found naming deficits for both word reading and picture naming in children with dyslexia in comparison to controls. Using PET they found reduced activation in a left occipitotemporal area during both tasks. They argued that underlying deficits in dyslexia may not be limited to orthographic decoding but may instead constitute a wider general impairment with difficulty in the integration of phonology and visual information.

2.2.3. Wider cognitive impairments and theories

There is an extensive body of research indicating a large range of wider cognitive impairments in dyslexia. These include the temporal processing (e.g. Tallal & Piercy, 1973), or the Dyslexic Automatisation Deficit (DAD) hypothesis (Nicolson & Fawcett, 1990), the magnocellular theory (Stein & Walsh, 1997), cerebellar deficit hypothesis (Nicolson, Fawcett & Dean, 2001), and executive functioning deficits (e.g. Varvara, Varuzza, Sorrentino, Vicari & Menghini, 2014), which can explain some of the wider, non-phonological range of deficits found in dyslexia.

2.2.3.1. The magnocellular theory

The magnocellular theory (Stein & Walsh, 1997) argued that there are visual and auditory deficits in developmental dyslexia. The central idea in the magnocellular theory of developmental dyslexia is that there is a processing deficit in the magnocellular pathway through which auditory and visual signal is carried to the sensory nerves.

2.2.3.1.1. Visual

Visual information from the retina is passed via parasol and midget ganglion cells (Darcy 1992) to specific pathways which have a specialised function in visual sensory perception; these are the magnocelluar (parasol ganglion cells) and parvocellular (midget ganglion cells) neural pathways. The midget and parasol ganglion cells meet at the back of the retina to form the optic nerve. Visual information is processed through the optic nerve to the lateral geniculate nucleus (LGN), which is comprised of six layers. Two layers receive information for larger ganglion cells forming the magnocellular route (known as the dorsal stream) and two layers receive information from smaller ganglion cells to form the parvocellular (known as the ventral stream) route (Schiller, Logothetis & Charles, 1990). Visual information is projected through the primary visual cortex to the inferotemporal cortex, known as the "what" pathway (mainly parvocellular) and parietal cortices known as the "where" (mainly magnocellular) pathway (Kaplan & Shapley, 1986; Goodale & Miller, 1992; Merrigan & Maunsell, 1993; Shapley & Perry, 1986). After extensive primate and human research, it is widely accepted that magnocellular and parvocellular neurons are tuned to respond optimally to different temporal and spatial frequencies (De Monasterio & Gouras, 1975; Derrington, Krauskopf & Lennie, 1984). The magnocellular system, while insensitive to isoluminant changes in colour polarity, responds optimally to low contrast and low spatial frequencies (i.e., coarse patterns) (Kaplan, Lee & Shapely, 1990; Lee, Pokorny, Smith, Martin & Valberg, 1990). The magnocellular system has a very high temporal resolution and is sensitive to extremely rapid changes in visual input (Nowak & Bullier, 1997; Schiller, Logothetis & Charles, 1990a, 1990b). The parvocellular system conversely has relatively lower temporal resolution but is sensitive to changes in colour and has superior sensitivity to high spatial frequencies (i.e., fine detail) (Kaplan et al., 1990; Kaplan & Shapley, 1986). The parvocellular pathway is relevant to fine detail information i.e. colour and high spatial frequencies, whereas the magnocellular pathway is relevant to visual information related to movement, low contrast and low spatial frequencies (McLean, Stuart, Coltheart & Castles, 2011; Eysenck & Keane, 2005; Kalat, 2007; Derrington, Krauskopf & Lennie, 1984).

The magnocellular theory of developmental dyslexia is based on a suspected deficit in the processing of information in the magnocellular pathway. This is argued to be the underlying cause of impairments in reading (Stein & Walsh, 1997; Stein, 2001; Stein & Talcott, 1999). The evidence supporting this claim comes from Lovegrove (1993) who found that children with dyslexia have slightly reduced sensitivity to low spatial frequencies and low luminance levels. The reduced sensitivity to low spatial frequency and low luminance levels, particularly during flicker, are related to the magnocellular pathway, whereas the higher spatial frequencies which were found to be intact in dyslexic children studied by Lovegrove (1993), are related to the parvocellular system.

Deficits identified in global motion perception/processing and low flicker fusion, in individuals with dyslexia, have been found to correlate with reading and spelling problems (Talcott, Hansen, Assoku & Stein, 2000). The magnocellular theory of dyslexia has also been supported by post mortem research conducted on brains of individuals with dyslexia. Galaburda and Livingstone (1993) found that the magnocellular layers of neurons in the lateral geniculate nucleus were 30% smaller in individuals with developmental dyslexia compared to controls. On the other hand, the parvocellular layers were found to be as normal (Livingstone, Rosen, Drislane, & Galaburda, 1991). The assumption made within the magnocellular deficit theory can be explained on the basis of the fact, that during reading there is a greater need for eye movement control and visual movement perception, which is mainly based on magnocells and the dorsal pathway. Difficulties in processing visual information via the magnocellular/dorsal pathway at both the retinal and higher pathway levels are argued to result in deficits in detection of global motion. This in turn can predict reading ability (Talcott et al., 2000).

McLean, Stuart, Coltheart and Castles (2011) argue that their research refutes a specific deficit in magnocellular temporal resolution, instead supporting the existence of an underlying pervasive deficit in low-level perceptual speed in some children with developmental dyslexia. McLean and collegues used a chromatic flicker perception task (where participants see a red/green LED light flicker at increased intervals until the separate lights appear to merge into a single orange light at around a flicker rate of 15 to 25 Hz), to investigate the functioning of both magnocellular and parvocellular visual temporal processing. A range of reading and phonological tests were conducted, as well as a test to find the fastest flicker threshold that could be used in the magnocellular system. The tasks used to test for an association between magnocellular temporal resolution and visual temporal processing were rapid naming (naming as fast as possible a series of different colour patches and a series of familiar pictures of objects such as a chair), inspection time (identifying the longer of two lines presented), go/no-go reaction time (series of traffic light colours where the light colour determined if a button should be pushed or not and reaction time and response inhibition and false alarm recorded), rapid serial visual presentation (RSVP) and the attentional blink (where a sequence of visual stimuli is presented in rapid succession, in the same spatial location and individuals are asked to detect a target which is presented twice). To measure sustained attention and response inhibition, a continuous performance task was incorporated, where participants had to press a button when they saw a particular shape (e.g. triangle), form a continual visual presentation of shapes, and then refrain from reacting when the shape was preceded (two shapes before the target shape) by another specific shape (e.g. square).

McLean et al. found that the dyslexic group had significant differences in magnocellular temporal resolution thresholds. They argued that even with these differences, several factors suggest that there is not a specific magnocellular temporal resolution deficit. Firstly, they argued that they did not find significant differences in the high-contrast condition, as would be expected in the magnocellular deficit theory. They also point out that correlation between reading ability and magnocellular temporal thresholds account for only 9% of variance in the reading measures (far less than that explained by language-based measures, phonological processing and rapid naming). Finally they also highlight that with a number of participants showing deficits in both parvocellular and magnocellular temporal thresholds, this did not bode well for the theory of a specific magnocellular system deficit (with only 10% showing a sole and specific magnocellular deficit). McLean et al. argued that individuals with dyslexia appear to show an overall deficit in low-level temporal processing. Using factor analysis McLean and colleagues found that a perceptual speed factor (made up of single-target RSVP performance, inspection time, go/no-go reaction time and magnocellular temporal threshold) was also a significant predictor of reading ability. They found that this predictor was independent of phonological processing, rapid naming and other general performance skills. Even though there is limited evidence showing that low-level visual magnocellular processing impairments contribute to reading difficulties in dyslexia independently of the deficit in phonological skills, the magnocellular theory shows that there are other, non-phonological deficits in dyslexia. Moreover, Iles, Walsh and Richardson (2000) found that dyslexic individuals are significantly worse in their performance on serial visual search tasks and this type of task has been also found to be dependent on magnocellular layers (Cheng, Eysel & Vidyasagar, 2004). In addition, Facoetti et al. (2001) found that individuals with dyslexia are vulnerable to distractors. These studies provide further evidence that deficits in dyslexia are not limited to linguistic processes.

2.2.3.1.2. Auditory

There has also been research that has found abnormalities in auditory magnocellular layers of the dyslexic brain e.g. Galaburda, Menard and Rosen (1994); Stein and Walsh (1997); Eden, VanMeter, Rumsey, Maisog, Woods and Zeffiro (1996). These findings in conjunction with the temporal auditory processing deficits present in dyslexia (Tallal & Piercy, 1973; Tallal, 1980) have constituted the basis of the auditory version of the magnocellular deficit theory of developmental dyslexia. This theory claims that the magnocellular temporal processing deficit results in a basic auditory processing impairment that is found in individuals with dyslexia. This impairment was argued to be found in low level auditory transient processing, which caused severe difficulties for individuals with dyslexia in distinguishing between similar phonemes when they occurred sequentially after each other, in short intervals.

2.2.3.2. Temporal processing theory

The temporal processing theory of dyslexia (e.g. Tallal & Piercy, 1973) argued for broader deficits in dyslexia, beyond difficulties with phonological processing suggesting that individuals with dyslexia have a deficit related to low-level auditory perception which is evidenced in the processing of rapid or brief sounds (Tallal & Piercy, 1973; Tallal, 1980). This general non-linguistic auditory temporal deficit theory is based on research which showed that dyslexic children have problems with the processing of brief and rapidly changing acoustic information (Tallal, 1980; Tallal et al., 1993; 1996). These studies used auditory temporal order perception tasks and found that individuals with dyslexia were worse on these tasks compared to normal readers. It is argued that for functions such as speech, learning and movement, the ability to discriminate between different sounds or visual material presented in rapid stimulus sequences, are vital (Hari and Renvall, 2001). Therefore, deficits found in rapid stimulus sequences were argued to be a contributory factor in some of the phonological processing difficulties found in children with dyslexia (Tallal et al., 1993).

Attentional processes and attention shifting have also been investigated, with Hari and Renvall (2001) postulating that individuals with dyslexia have difficulty in switching between tasks, labelling this as, “sluggish attentional shifting”. They propose that sluggish attentional shifting is the pathophysiological link between the magnocellular deficit and the impaired rapid stimulus sequence processing in dyslexia. In their review of research into the processing speed of rapid stimulus sequence tasks they found that in comparison to controls, the dyslexic participants took longer to switch attention between a variety of tasks. These included an auditory saltation illusion, a pitch streaming, and visual temporal-order judgment task (outlined below).

Hari and Kiesilä (1996) investigated rapid auditory stimulus sequences in an auditory saltation illusion task where four binaural clicks are presented in each ear at interstimulus intervals of 500ms. Participants were able to recognise that the first four clicks were first presented in one ear, while the next four clicks were presented in the other ear. The interstimulus intervals were gradually reduced to 30ms, which created a saltatory percept; causing the sounds to appear further apart when the sounds changed between ears in comparison to when they were heard in the same ear. Adding another binaural click in the right ear (4 left, 5 right), appears to the listener, to make the whole stimulus sequence jump. Dyslexics perceived the stimulus sequence jump effect at significantly longer intersound intervals than controls (typical readers). It was argued that the longer intersound intervals required for this effect may explain some of the deficits in dyslexia, with longer sound intervals being likely to result in interference on rapidly presented auditory stimuli, in individuals with dyslexia (Hari and Kiesilä, 1996; Hari and Renvall, 2001).

This finding was later supported by Helenius, Uutela and Hari (1999) in a “pitch streaming” task, where they found attentional deficits in the dyslexic group. High and low tones were presented alternately to participants and they were perceived as separate tones (i.e. high tone followed by a low tone, then another high and low tone and so on). When the interval between the sounds (tones) is shortened, listeners should perceive two separate continuous streams of high and low tones. Helenius et al. (1999) found that in order for participants with dyslexia to perceive the tones to form two separate streams of sounds (one continuous high tone and one continuous low tone), they needed twice as long an intertone interval compared to controls. This finding suggested dyslexic individuals have difficulties in processing rapid stimulus sequences. Helenius et al. (1999) also provided further support suggesting that sluggish attentional shifting deficits may account for problems seen in phonological processing in individuals with dyslexia. They looked at correlations between stream segregation and a series of tasks including; working memory, naming speed, reading speed and timing of lexical decisions using words and pseudo-words. The pseudo-words were recognised more slowly by the dyslexic group and the naming speed was slower than controls. These findings also correlated with results on the pitch streaming task and were argued to support the view of sluggish attentional shifting, with the dyslexic group appearing to have a longer time window between recognising two sequentially presented sounds, thus creating the possibility of sound interference between the two stimuli.

Hari, Valti and Uutela (1999) used an attentional blink task to measure the dwell time between identifying one letter stimulus and then the requirement to detect if the letter “x” followed it or not. When disengaging from one stimulus and engaging in another stimulus, the dwell time is expected to be around 400-600ms and it is generally argued that this dwell time is likely to be caused by a limitation in capacity (Duncan, Martens & Ward, 1994; cited in Hari and Renvall, 2001). It was found that dyslexics had a mean response time of 700ms in comparison to 540ms (at 75% performance level) for controls. This finding provide strong evidence that individuals with dyslexia have deficits in disengaging from one item in order to engage in the processing of the next item, when faced with rapid stimulus sequences (Hari et al.,1999; Hari and Renvall, 2001). Hari et al. (1999) postulated that the extended dwell time before identifying a new target stimulus in the dyslexic group extends the use of additional capacity by around 30% in comparison to control.

Hari, Renvall and Tanskanen (2001) investigated the underlying mechanisms that may account for the observed deficits in dyslexia. Hari et al. (2001) argued that the attentional blink task relies heavily on automatic attention (Hari et al.,1999), with brain imaging showing the magnocellular pathway (visual neural pathway) being involved in the efficient use of capacity-limited attention processing by sending information to the right parietal lobe. Therefore, any deficit in the magnocellular pathway or right parietal lobe may explain deficits in dyslexia. The dyslexic group demonstrated a right visual field advantage in comparison to controls in a visual temporal-order judgment task, requiring participants to indicate verbally whether a visual bar in the left (or right) hemisphere preceded a similar bar on the right (or left) two sequentially presented stimuli. The same advantage was also demonstrated by the dyslexic group in a line motion illusion task, where individuals had to state if a line (that appeared to grow from a specific cued point on a computer screen) moved from left to right of the screen. They argued that the parietal lobe is important in learning to read as it has an important function in attentional shifting and that reading requires extensive use of attentional shifting (Hari et al., 2001; Hari and Renvall, 2001) to read a sequence of letters that make up words; and that deficits in attentional shifting may account for many of the reading deficits witnessed in dyslexia.

Other research in visual, auditory, tactile unimodal and crossmodal perception have also supported the deficits found in children and adults with dyslexia in rapid temporal processing (e.g. Laasonen, Tomma-Halme, Lahti-Nuuttila, Service & Virsu, 2000; Laasonen, Service & Virsu, 2001; Hari,1995; Hari et al., 2001; Helenius et al.,1999). Support for Hari and Renvall's

(2001) belief that sluggish attentional shifting deficits could account for phonological impairments seen in dyslexia came from Lallier, Tainturier, Dering, Donnadieu, Valdois and Thierry (2010). They investigated automatic attentional shifting in both auditory and visual modalities using behavioural and ERP measures, finding deficits in both modalities in relation to speed of processing and argued that sluggish attentional shifting could account for the phonological impairment in developmental dyslexia. Conversely, Moores, Nicolson and Fawcett (2002) attributed deficits in rapid switching to a lack of automatisation of basic skills in individuals with dyslexia.

2.2.3.3. Dyslexic Automatisation Deficit

The Dyslexic Automatisation Deficit (DAD) hypothesis was proposed by Nicolson and Fawcett (1990). Nicolson and Fawcett argued that dyslexia is not just limited to reading difficulty but rather that the reading difficulty is just a symptom of a more general and pervasive deficit in the acquisition of skill. According to the DAD hypothesis, children with dyslexia find it abnormally difficult to automatise skills, even when they have practised them extensively. This problem with automatisation has been argued to be relevant to both cognitive and motor skill acquisition. Moreover, the DAD hypothesis claimed that this deficit can be masked by situational factors or coping strategies enabling individuals with dyslexia to mask this deficit in tasks which are not demanding. Nicolson and Fawcett (1990) based these assumptions on the results from the British National Cohort Study (e.g. Haslum, 1987), in which close observation of children with dyslexia and discussions with their parents indicated frequent problems with basic skills, which could be masked if children actively allocated additional attentional resources to the task.

This reasoning led Nicolson and Fawcett (1990) to the development of the Conscious Compensation (CC) hypothesis, which argued that children are consciously concentrating (i.e. using or engaging controlled processing) on performance, in order to consciously compensate for deficits in phonological skill, naming speed, motor skill and balance, which result from deficits in skill automatisation. This conscious compensation enables children with dyslexia to perform at apparently normal levels during tasks that should usually be automatic. In other words, the CC hypothesis argued that children with dyslexia can achieve performance on a wide range of tasks which is comparable to the performance of normally developing children, but this requires children with dyslexia to “work harder” in order to achieve this (i.e. by consciously allocating attentional resources). Furthermore, the CC hypothesis argues for three well-known features of performance deficits in individuals with dyslexia, namely that performance drops in resource-intensive tasks; performance is especially likely to be influenced by stress; and that performance can be maintained only over relatively short periods.

Nicolson and Fawcett (1990) chose the gross motor skill of balance to investigate a non-phonological skill in children with dyslexia and test the DAD/CC hypothesis. In addition, Nicolson and Fawcett wanted to make sure that the skill to be used to test the DAD/CC hypothesis was fully automatic in children. The reason for choosing balance was that children would have very extensive practice in this skill. Furthermore, balancing is probably the most practiced skill of all skills and therefore it is very likely that it is fully automatised.

An advantage of choosing a skill which is fully automatised is that it does not require conscious effortful monitoring (Nicolson & Fawcett, 1990). Thus, the authors argued that fully automatised skills, even in the presence of other task demands that draw on conscious processing capacity, will not result in major decrements in performance. This will enable any deficits in automatisation to become visible in tasks where conscious monitoring is harder to perform. Therefore, Nicolson and Fawcett argued that, if there is an automatisation deficit in dyslexic children, it should be visible under conditions that make conscious monitoring more difficult. This led Nicolson and Fawcett to use a dual-task paradigm in order to investigate whether there was an automatisation deficit in children with dyslexia. Their use of a secondary task to take away attentional resources from the primary task (balancing) made conscious compensation more difficult. Therefore, if the DAD/CC hypothesis is true, a deficit in automatisation should become visible.

Nicolson and Fawcett (1990) tested 23 children with dyslexia (around 13 years old) of normal or above normal IQ (IQ over 90), and eight non-dyslexic children matched for age and IQ. This study included three tasks: standing on both feet on a block (with one foot being placed directly in front of the other); walking; and standing on one foot. Participants had to perform these balance tasks under single and dual-task balance conditions. In the single-task balance condition participants were required just to balance and in the dual-task balance condition they had to perform an additional task. Thus, participants were required to balance and perform a secondary task at the same time. There were two versions of the secondary task in the dual-task balance condition. One secondary task involved counting and the other was a choice reaction task.

The results of this study showed that under single-task balance conditions (one foot, beam walking and balance) there were no significant differences in balancing ability between the children with and without dyslexia. However, the dual-task balance condition revealed a strong reduction in balancing performance for individuals with dyslexia when compared to the single-task condition; with this decrease in performance not being present in the control participants. Nicolson and Fawcett suggested that individuals with dyslexia used conscious compensation to mask their automatisation deficit when performing this task. In addition, children with dyslexia showed decrements in the secondary task which involved counting. This decrement in the performance on the secondary task was not present in the performance of control children. This finding suggested that there is a problem with fully automatising skills in children with dyslexia in the presence of a secondary task. The authors argued that the results of this study supported the DAD and CC hypotheses. However, as acknowledged by Nicolson and Fawcett, the impaired performance on the secondary counting task could be argued to be related to the nature of the task. Namely, counting involves a range of phonological skills and therefore it is possible that the dyslexic children performed worse on this task due to their phonological deficit.

Nonetheless, the second experiment conducted by Nicolson and Fawcett (1990) employed a different secondary task, an auditory choice reaction task, which did not involve phonological skills. This task required participants to indicate (by pressing a left or right button) as quickly as possible whether they heard a high or low tone. The results showed that children with dyslexia were significantly slower and less accurate on this non-phonologically based task. This, in addition to finding no significant differences in balancing under the single-task condition, again supported the hypothesis that dyslexics use conscious compensation in easier tasks and are unable to compensate under more demanding task conditions.

However, auditory processing has been also found to be affected in dyslexics (as stated by the magnocellular hypothesis; Stein & Walsh, 1997) and it may be argued that this created the difference in performance on the secondary tasks used in the second experiment. Nonetheless, it can be still argued that performing this secondary task has drawn away resources from the primary task, not allowing individuals with dyslexia to consciously compensate for their automatisation deficit. Thus, this could have resulted in impaired performance on both tasks (the balancing and the auditory choice reaction tasks).

Alternatively, it could be argued that the dual-task paradigm in general created cognitively demanding conditions, which were too demanding for children with dyslexia and resulted in worse general performance (on both tasks). Since dyslexic children did not show any deficit under single-task conditions (involving balance), but there were deficits visible under the dual-task conditions. Moreover, Nicolson and Fawcett (1990) provided an additional interpretation of the results apart from the DAD hypothesis. Namely, they suggested that it is possible that children with dyslexia also have a general problem with the allocation of attention leading to impaired performance under dual-task conditions. Additional evidence also indicated attentional problems in children with dyslexia (e.g. Dykman, Ackerman & Holcomb, 1985).

Further support for the DAD/CC hypothesis was shown by Fawcett and Nicolson's (1992) study in which they tried to establish whether the dual-task difficulties in dyslexia were due to the prevention of conscious compensation, or due to a broader attentional deficit occurring in situations requiring performance of two tasks simultaneously. In this study Nicolson and Fawcett blindfolded their participants in order to stop them trying to consciously compensate. This study did not manipulate the difficulty of a secondary task. The dyslexic children showed an impaired automatisation of balancing skill compared to controls under blindfolded balance conditions. Thus, in this study individuals with dyslexia performed worse than controls, as they were not able to employ conscious compensation.

In summary, the DAD hypothesis stated that children and adults with dyslexia have difficulties in automating skills and as a result they need to employ conscious compensation in order to perform at normal levels. Nicolson and Fawcett (1990) argued that skills which non-dyslexic individuals can perform well can eventually be performed well by dyslexics. However, Nicolson and Fawcett argued that these skills will require participants with dyslexia to consciously attend to aspects of performance that come without the use of additional cognitive resources for non-dyslexic children.

2.2.3.3.1. Cerebellar deficit theory

The cerebellar deficit theory of dyslexia (Nicolson & Fawcett, 1990; Nicolson et al., 2001) was developed from an accumulation of evidence of automatisation problems found in the DAD studies. The cerebellar deficit theory of dyslexia is based on the claim that underlying deficits in the functioning of the cerebellum in individuals with dyslexia, can explain the problems with automatisation of skills (neural correlate of DAD theory) and more broadly in cognitive deficits in dyslexia. Recent functional neuroimaging and neurophysiological research have suggested that the cerebellum is involved in not only motor skills but also in wider cognitive functions and that deficits in the distribution of activity in the cerebellar can provide an explanation for the underlying deficits found in dyslexia (Baillieux, Vandervliet, Manto, Parizel, De Deyn & Mariën, 2009; Nicolson, Fawcett, Berry, Jenkins, Dean & Brooks, 1999).

The cerebellum is a very densely packed and deeply folded subcortical structure that is situated in the hindbrain (Holmes, 1939). This large area of the brain contains a large proportion of the brain's neurons (Brodal, 1981). The cerebellum is argued to be responsible for the coordination of motor control (Kalat, 2007; Lacourse, Orr, Cramer & Cohen, 2005) and other cognitive deficits such as language production (e.g. Baillieux, Vandervliet, Manto, Parizel, De Deyn and Mariën, 2009). Levisohn, Cronin-Golomb, Schmahmann (2000) found that the cerebellum as part of a distributed neural network, is particularly important in higher order cognitive functioning (e.g. planning and sequencing, visual–spatial function, expressive language). Time estimation deficits have also been linked to the cerebellum (Nicolson, Fawcett and Dean, 1995), with children who have dyslexia showing difficulties in estimating the time difference between auditory tones but not on detection of how loud the sounds were. This finding supported Ivry and Keele's (1989; cited in Nicolson & Fawcett, 2010) study involving individuals who had cerebellar lesions and patients with other neuropsychological disorders. They suggested that time estimation was linked to the cerebellum as the patients who had cerebellar lesions had specific deficits in estimating the duration of time between auditory tones.

A number of brain imaging studies have supported the metabolic and anatomical activation differences of the cerebellum in dyslexic individuals e.g. Rae, Lee, Dixon, Blamire, Tompson, Styles et al. (1998); Nicolson, Fawcett, Berry, Jenkins, Dean and Brooks (1999); Brown, Eliez, Menon, Rumsey, White and Reiss (2001); Leonard, Eckert, Lombardino, Oakland, Kranzler, Mohr et al. (2001). Another study supporting cerebellar differences in individuals with dyslexia was conducted by Finch et al. (2002) who re-analysed brain specimens of dyslexic individuals originally studied by Galaburda et al. (1994). This re-analysis found that the small and large cerebellar neurons of non-dyslexic and dyslexic individuals differed significantly in numbers.

The mild impairment of the cerebellum in individuals with dyslexia is related to poor performance on a wide range of motor tasks (Fawcett, Nicolson & Dean, 1996) e.g. poor balance, late crawling and walking and exceptional clumsiness (Reid et al., 2008). These problems with motor control affect also the motor side of speech production which is essential for accurate discrimination between different sounds. Moretti, Bava, Torre, Antonello and Gazzato (2002) found that individuals with cerebellar lesions had problems with language compared to controls. A number of neuroimaging studies have indicated that the cerebellum is involved in language production e.g. Baillieux et al. (2009); Finch, Nicolson and Fawcett (2002); Rae et al. (2002). Baillieux, et al.(2009) used a semantic association test, where they presented participants with ten different nouns (3 seconds apart from each other), asking them to silently generate semantically related verbs. Using MRI technologies they found that children with dyslexia demonstrated a more diffuse network activation which was spread across the left hemisphere (incorporating the frontal, temporal, parietal and occipital regions). In comparison to controls, who showed activation in anterior regions of the right hemispheric, dyslexics activated the precentral gyrus and in the posterior parts of the occipital lobe. Baillieux et al. (2009) therefore argued that widespread activations on the cerebral and cerebellar level, suggests that the processing of information in the cerebellar cortex was disordered. Baillieux et al (2009) argues that their findings support research by Milne, Syngeniotis, Jackson and Corballis (2002), Seki et al. (2001) and Shaywitz et al. (2002) on a variety of linguistic tasks (e.g. sentence reading, lexical decision and verb generation), where similar patterns of activation were found across the left hemisphere and the right posterior hemisphere. Nicolson, Fawcett, Berry, Jenkins, Dean and Brooks (1999) have argued that a deficit in the ability to automate basic articulatory skills and auditory skills coupled with difficulties in fine motor control (eye movement and letter recognition), can help explain many of the difficulties seen in dyslexia in relation to learning to read and write.

The cerebellum has been hypothesised to be not only involved in motor skill, but also in skill automatisation and in adaptive learning control e.g. Ito (1990); Jenkins, Brooks, Nixon, Frackowiak and Passingham (1994); Krupa, Tompson and Tompson (1993). Furthermore, the cerebellum has been proposed to be crucial not only in the automatisation of motor skill, but also in the automatisation of cognitive skill (Leiner, Leiner & Dow, 1991; 1993). The skills arguably affected by the deficit in automatisation caused by dysfunction of the cerebellum include overlearned tasks such as learning to ride a bicycle or reading (Ramus et al., 2003).

The involvement of the cerebellum in WM and attention has been now established by the means of studies investigating patients with cerebellar damage who showed deficits in these cognitive areas (Malm, Kristensen, Karlsson, Carlberg, Fagerlund & Olsson, 1998; Ravizza, McCormick, Schlerf, Justus, Ivry & Fiez, 2006). Furthermore, Nicolson, Fawcett, Moss, Nicolson and Reason (1999) found that cerebellar activation was only 10 to 20 % of the expected level in adults with dyslexia performing motor learning tasks. This study employing PET technology provided further evidence of cerebellum deficit in dyslexia.

2.2.3.4. Working memory in dyslexia

There is a large body of literature concerning problems with WM in dyslexia (e.g. Chiappe, Hascher & Siegel, 2000; Griffiths and Snowling, 2002; McDougall & Donohoe, 2002; Plaza, Cohen & Chevrie-Muller, 2002; Roodenrys & Stokes, 2001). McLoughlin, Fitzgibbon and Young (1994) have argued that deficient WM is one of the central characteristics of dyslexia and that it affects dyslexic individuals throughout their life. There is an extensive body of research supporting the phonological deficit hypothesis, with poorer storage capacity of the phonological loop component of WM (e.g. Helland & Asbjørnsen, 2004; Jorm, 1983; Palmer, 2000; Frith, 1985; Stanovich, 1988; Vellutino et al., 2004). There is also some evidence showing a visuo-spatial deficit related to storage capacity in dyslexics (e.g. Olson & Datta, 2002), although other papers argue against this deficit (e.g. Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007). In reviewing the visuo-spatial sketchpad, Swanson (1978) asked poor readers and controls to remember nonsense shapes. Half of the participants for each group were given names for the shapes (phonological loop component) whilst the other half had to remember the physical shape in memory, using the visuo-spatial sketchpad. Visuo-spatial deficits were not identified, with no significant differences between the groups in the condition where the shapes were not named. However, when the shapes were named the controls performed better than the dyslexic group; demonstrating deficits in the phonological loop but not the visuo-spatial sketchpad.

Researchers have begun to consider if individuals with dyslexia are limited to a domain specific deficit within the phonological component of WM or if wider domain general deficits exist in the CE processing function of WM. Swanson (1994) looked at phonological, visuo-spatial processing (short-term memory) and CE function (storage and manipulation of information) in relation to literacy in children and adults with dyslexia. He found deficits in the phonological short-term memory component and the CE, but not the visuo-spatial component. Pickering and Gathercole (2004) findings supported that of Swanson (1994); on two tests of CE (backward digit span and counting recall), the dyslexic group showed deficits in relation to controls matched for reading age. In an attempt to tease apart the nature of WM deficits in dyslexia, Smith-Spark et al. (2003) conducted several experiments using Baddeley's (1986) WM model.

In an attempt to understand the involvement of the phonological loop and CE in reading deficits found in dyslexia, Smith-Spark et al. (2003) administered two short-term memory tests (digit and word span), as well as a letter updating task that was expected to draw upon the central executive component of WM and the phonological loop. The letter updating task required participants to remember (in the order presented) the last six consonants from a varied sequence containing 6, 8, 10 and 12 consonants. If more than six consonants were presented, participants needed to update the contents of WM by deleting redundant information and repositioning items in serial order (Postle et al., 2001). To demonstrate CE involvement, participants would need to hold the information in memory (phonological loop) and then update the items (in serial order) as they received more stimuli. However, whilst Smith-Spark and colleagues also found that the dyslexic group performed significantly worse than controls on the letter updating task; the deficits showed a recency effect with participants being able to better recall the most recently presented of the six letters in comparison to the first few letters (with more errors occurring in the first few letters of the last 6 to be recalled). With the failure occurring so early on, this pointed to a deficit in the phonological loop processing stage. Thus, for the dyslexic group they appeared to be using a recency effect process and there was little or no evidence of involvement of the CE. For the digit and word span, participants were presented with digits or words and asked to recall the list. As expected, the results confirmed deficits on the phonological (verbal) component of WM with deficits evident in the digit span and word span tasks.

With the letter updating task being argued to tap into phonological processing rather than being a reliable test of the CE, Smith-Spark et al. (2003) opted to utilise a visuo-spatial measure to test the CE, independently of phonological impairments associated with dyslexia. Visuo-spatial WM can make both "static" (short-term memory of location of simultaneously presented stimuli) and "dynamic" demands on resources (recall of both order and location of stimuli). Smith-Spark et al. (2003) administered a static memory task (in which participants had to recall visuo-spatial location of seven simultaneously highlighted cells in a 5x5 grid matrix), and to test the CE component of WM, they used a dynamic task (in a 5x5 grid matrix, several cells are highlighted sequentially and participants have to recall both the location and order of presentation). An additional spatial updating task was administered. This task required participants to remember the last four locations and order of presentation of highlighted cells from a varied sequence containing 4, 6, 8 and 10 highlighted cells. With the static and dynamic tasks being visuo-spatial in nature, any deficits found could be argued to be independent of the phonological loop. Whilst results indicated that there were no significant differences between groups on their ability to recall static or dynamic spatial memory tasks, there were specific differences in the updating task. Smith-Spark et al. (2003) found that individuals with dyslexia were significantly worse, but only when the updating task employed a high cognitive load. Thus, the dyslexic group made more errors when recalling the last 4 positions in the updating task when they were given higher sequences (10 different locations) of highlighted spatial locations. Similar to their first experiment dyslexic participants demonstrated a recency effect, having difficulty remembering the serial order position of the first two highlighted cells when required to store the location and serial order of 10 sequentially presented cells. The researchers argued that these deficits were additional to, and cannot be accounted for, by the phonological deficit theory of dyslexia. With the pattern of results it was argued that a domain-general CE deficit was the most likely factor, as differences between groups were only apparent when cognitive demands during the updating task in the visuo-spatial component were high.

As discussed in section 2.2.3.3., adults with dyslexia have been argued to be able to compensate for many of the difficulties associated with dyslexia. Nicolson and Fawcett (1990) demonstrated that children with dyslexia were able to mask their impairments on a range of tasks by the means of conscious compensation (CC). Smith-Spark et al. (2003) argued that their finding of group differences under most cognitively taxing condition is in line with Nicolson and Fawcett's (1990) DAD/CC hypothesis. Smith-Spark et al. (2003) reasoned that the deficit visible in adults with dyslexia, in the most complex task may be linked to their inability to consciously compensate. Under low task complexity, dyslexic and control groups performed comparably. However, when task complexity was high, the CE or SAS (Norman & Shallice, 1986) of dyslexic individuals has been argued by Smith-Spark et al. (2003) and Smith-Spark and Fisk (2007) to be unable to allocate extra resources to the task, resulting in poorer performance (compared to controls). The pattern of results in Smith-Spark et al. (2003) supports this position, with the performance of individuals with dyslexia differing significantly from the performance of controls, only when the task complexity increased. That is, when there were a greater number of updates required there was a drop in performance observed in dyslexics relative to controls. This reasoning was supported using Swanson, Ashbaker and Lee's (1996; cited in Smith-Spark et al., 2003) argument, that higher processing demands result in verbal and visuo-spatial WM deficits in individuals with reading disability. Smith-Spark et al. (2003) purported that their findings indicate a deficit in EF in individuals with dyslexia; which is evidenced in phonological and visuo-spatial processing. When tasks placing high demands on executive resources are administered, deficits in CE are evident, with it being argued that dyslexic individuals are unable to allocate resources in order to consciously compensate for this deficit (Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007), as available resources are fully allocated to the task in hand.

Smith-Spark and Fisk (2007) extended their research on CE deficits by comparing dyslexic and non-dyslexic performance across phonological and visuo-spatial domains of WM. They compared tasks that required short-term storage of digit, letter, word and spatial span (in the form of a Corsi block task), against tasks that measured complex verbal and visuo-spatial WM span (requiring storage and processing of information). These tasks included a computation and word span (working out a series of arithmetic or sentence problems, whilst remembering the last digit or word from each problem), and a spatial WM span. The spatial WM task consisted of a split screen displaying a range of boxes with only five being highlighted (four are filled with "X's" and one with "O"). Participants were required to select which half of the screen contained more highlighted boxes, whilst remembering the position of the highlighted box filled with "O". Sequences of trials were used with participants having to report the location of each of the boxes filled with "O's" in the order presented. Finally, two updating tasks (consonant and spatial span) which required additional CE resources were administered. The consonant span task is explained above in Smith-Spark et al.'s (2003) study description. The updating spatial span task used an adapted Corsi block design, where participants were presented with a screen of blank boxes with some of the boxes (randomised selection of up to 12 boxes) highlighted (one at a time), and asked to recall the last four boxes highlighted (in serial order presented), at the end of the trial.

Smith-Spark and Fisk (2007) found significant deficits in dyslexic participants compared to controls on both the simple and complex span tasks, as well as in the updating tasks. Their findings not only support the phonological deficits found in WM (e.g. Smith-Spark et al., 2003) in dyslexia, but also suggest visuo-spatial WM deficits. After controlling statistically for simple span tasks, Smith-Spark and Fisk (2007) postulate that deficits are still found on the complex span tasks, therefore suggesting a CE impairment in dyslexia which is independent of the phonological loop or visuo-spatial sketchpad components of WM. Upon analysing the difference in performance between the first half and second half of the spatial updating task, Smith-Spark and Fisk (2007) found that dyslexic individuals showed a significant disadvantage during the first half of the WM task, but not during the second half. This showed that individuals with dyslexia found the task significantly more difficult compared to controls, when first encountering the spatial updating task. However, the dyslexic group were eventually able to catch up with controls on the task, after adapting to task demands. This led Smith-Spark and Fisk (2007) to claim that in dyslexia, the problem is with the novelty of the task and that once schemas are in place to recognise what is required, this deficit diminishes. Novel tasks have been argued to strongly involve executive control processes (e.g. Rabbitt, 1997; Shallice &

Burgess, 1993). Thus, Smith-Spark and Fisk concluded that there is a problem with executive control processes for individuals with dyslexia.

Smith-Spark and Fisk (2007) explained the executive dysfunction present in dyslexia in terms of the model of the attentional control of action proposed by Norman and Shallice (1986). Schneider and Shiffrin (1977) stated that action can be either conscious or automatic. Automatic processing is relatively non-demanding on attentional and processing resources whereas controlled processing draws on these resources. Because automatic processing does not require attentional and processing resources, it leaves these resources relatively free for higher-level processing. Controlled action on the other hand is mediated through the SAS which regulates behaviour via the control of attention. Deficits in the first half of the spatial updating task appear to happen when the task is still novel, therefore the deficits found could be argued to be due to the additional, conscious attentional resources (SAS involvement) required to create schemas, in order to automate many of the processes (Smith-Spark & Fisk, 2007).

Smith-Spark and Fisk (2007) linked the deficit in performing novel tasks to a deficit in SAS. They argued that the SAS is responsible for controlling non-automatic actions which are not well-learned or simple in nature. In addition, the SAS which controls, coordinates and integrates information can be affected negatively by distraction (e.g. high task demands; Norman & Shallice, 1986). As described earlier in this chapter, Fawcett and Nicolson (1994) argued that complex skills which require fluency in component sub-skills, multi-modality skills involving the monitoring of various modalities/sources of information, skills which depend on time which require fast speed of processing and vigilance tasks which require concentration over time, are all vulnerable to disruption in individuals with dyslexia. The tasks involving these skills create demands which prevent the use of CC to direct performance. These conditions in which the performance of dyslexics is vulnerable are similar to the task conditions which call upon the SAS. This suggests a deficit in SAS of individuals with dyslexia (Smith-Spark & Fisk, 2007), which is visible in complex tasks where individuals are not able to consciously compensate for their automaticity deficit. The automatisation/CC theory (Nicolson & Fawcett, 1990) claims that it is the failure to fully automatise skills that is responsible for a poorer performance in individuals with dyslexia (compared to controls) under cognitively demanding dual-task conditions. The authors stated that children were able to mask their automatisation deficit on easier tasks. Children with dyslexia were unable to mask their deficit, as their coping strategies were not great enough to cover the deficit present on the cognitively demanding dual-paradigm tasks.

In addition, Smith-Spark and Fisk (2007) have argued that the problem with performance of novel sequences in dyslexia was in line with the cerebellar deficit hypothesis of Nicolson et al. (1995; 2001). This has been argued in light of evidence that learning new skills and the execution of learned skills and WM and executive attentional control processes have been found to be dependent on the cerebellum (e.g. Ito, 1990; Justus & Ivry, 2001; Malm, Kristensen, Karlsson, Carlberg, Fagerlund & Olsson, 1998).

It can be concluded that WM deficits in dyslexia have been found in relation to the storing capacity of the phonological loop but there is mixed evidence on deficits in the visuo-spatial sketchpad. Smith-Spark et al. (2003) found a processing deficit in the phonological domain. Similarly Smith-Spark and Fisk (2007) found a processing deficit in the visuo-spatial domain of WM. This evidence appears to support CE impairments in individuals with dyslexia. Working memory in dyslexia will be discussed further in Chapter 7.

2.2.3.4.1. Dyslexia and executive functioning

Baddeley (1986; 2000) has claimed that the CE is involved in the allocation of resources, binding of information, shifting between tasks or retrieval strategies and inhibition of responses as well as in managing information, whilst performing other temporal activities. Support for CE deficits in dyslexia has come from a range of research in the areas listed above (e.g. Smith-Spark & Fisk, 2007). Swanson (2006) argued that executive system deficits extend beyond phonological processing in children with reading disabilities. He stated that children with reading difficulties have problems in different executive functions i.e. inhibition of irrelevant information, accessing material in long-term memory, and maintenance of relevant information in WM.

Palladino, Cornoldi, De Beni and Pazzaglia (2001) have argued that there are problems with updating information and inhibition of distractors in individuals with reading disabilities. Borella, Carretti, & Pelegrina, (2010) supported these findings in research that investigated inhibition in good and poor reading comprehension in relation to WM. They specifically examined resistance to proactive interference (to reduce the activation of stimulus that is no longer relevant to reduce intrusion errors), response to distracters (concentration on relevant stimulus whilst ignoring distracters) and prepotent response inhibition (inhibiting automatic cognitive or motor response to stimuli). Borella et al. (2010) found that poor comprehenders (in comparison to good comprehenders) were specifically susceptible to intrusion errors, as they found it difficult to eradicate stimulus that were no longer relevant. This deficit was found in both words and numbers and Borella and colleagues argued that this demonstrates that proactive interference occurs even when information is not processed semantically. They also postulated that WM deficits are a specific trait of poor comprehenders thus, when poor comprehenders continue to hold information that is no longer required in memory this overloads WM, causing poorer performance in the form of intrusion errors. Research has indicated a range of EF problems in children with dyslexia e.g. difficulties with problem solving (McLeskey, 1980), planning abilities (Weyandt, Rice, Linterman, Mitzlaff, & Emert, 1998) and both set shifting and organisation (Narhi, Rasanen, Metsapelto, & Ahonen, 1997). Moreover, according to a meta-analysis conducted by Booth, Boyle and Kelly (2010) on a total of 48 studies investigating EF in children with reading difficulties, there are a range of EF impairments in reading disabled children.

Varvara, Varuzza, Sorrentino, Vicari and Menghini (2014) found a wide range of EF deficits in children with developmental dyslexia employing a sample of 60 dyslexic children and 65 control children and a number of EF tasks. Namely, they found deficits in verbal phonological and categorical fluency, spoonerism, verbal and visual short-term memory, visual-spatial and auditory attention and verbal WM deficits. Varvara et al. (2014) findings supported the argument that a number of EF deficits found in dyslexia (to some degree) involve phonological processes. For instance, this study supported previous findings related to a deficit in verbal categorical fluency (e.g. Snowling, 2000; Ramus et al., 2003) and phonological fluency (e.g. Snowling, 2000). These two abilities have been argued to involve complex cognitive processes e.g. self-monitoring and flexible thinking (Schwartz, Baldo, Graves & Brugger, 2003). In addition, Varvara and colleagues found a deficit in dyslexia in the spoonerism task which assesses phonological awareness. However, the authors of this research argued that the spoonerism task also creates other extra task demands involving various skills e.g. blending skills, close monitoring of phonological manipulation and inhibition. Poorer performance of individuals with dyslexia on the spoonerism task has been reported in the literature previously (e.g. Jeffries & Everatt, 2004). Varvara et al. argued that the complexity of the spoonerism task could be responsible for the deficiency in the performance found on this task, for individuals with dyslexia. The results of the Varvara et al. (2014) study supported the already established problem in auditory attention in individuals with dyslexia (e.g. Ramus et al., 2013), within the EF literature. Furthermore, this study found a verbal short-term memory and WM deficits in dyslexia. All of these executive functions involve some degree of phonological processes.

However, Varvara et al. (2014) argued that the results from their study showing EF problems in children with dyslexia have also shown that the deficits in dyslexia are not only related to phonological processing, but also to non-phonological processes. For instance, this study found deficits in visual-spatial attention in children with developmental dyslexia. The authors postulated that the visual attention deficit found in their study, is in line with a deficit in automatic control of visual attention, (Facoetti, Lorusso, Paganoni, Cattaneo, Galli & Mascetti, 2003; Facoetti, Paganoni, Turatto, Marzola & Mascetti, 2000; Facoetti et al., 2001; cited in Varvara et al., 2014) and a deficit in rapid focussing of visual attention (e.g. Brannan & Williams, 1987; cited in Varvara et al., 2014), which were previously identified in dyslexia. The authors interpreted the findings as showing a WM deficit, in the context of a deficient functioning of the CE component of WM or the SAS (Norman & Shallice, 1986; Shallice, 1988). Varvara et al. (2014) suggested that, as EF tasks used by them may involve a large number of processes, which draw on visual and auditory domains (e.g. inhibition, short-term storage, attention, updating and integration of information), it is possible that the deficits found in dyslexia are underpinned by a more global CE/SAS deficit. Moreover, they claimed that there is a more global deficit in higher-order cognitive processes in developmental dyslexia. These suggestions of CE/SAS and EF deficits in developmental dyslexia are in line with findings from Smith-Spark et al. (2003) and Smith-Spark and Fisk (2007).

Reiter, Tucha and Lange (2005) investigated WM as well as a variety of executive functions in dyslexia. They identified WM deficits in children with dyslexia, with this group having poorer performance compared to controls on a backward digit span task. This task required participants to not only temporarily store information (numbers) but manipulate them and then repeat them in backwards order (e.g. “1,2,3” is repeated as “3,2,1”). They also found that children with dyslexia were impaired on a range of EF’s including inhibition, verbal and figural fluency and problem solving. Individuals with dyslexia showed deficits in inhibition but only when the tests were more cognitively demanding. Process time was also identified as an issue in inhibition deficits with the dyslexic group displaying longer processing time in some inhibition tasks. Planning and problem solving using a Tower of London problem solving task (Shallice, 1982) also showed deficits, these were related to the time taken to solve the problem (planning time) and not in the overall number of moves taken to solve the problem. They argued that in the deficits seen in EF, planning and problem solving tasks may be due to the dyslexic group needing additional processing time. Figural fluency tests identified that children with dyslexia created fewer designs (creating as many different designs by connecting 5 fixed dots using straight lines in 2 minutes) than controls. Deficits were also found in both semantic and formal verbal fluency in the dyslexic group, with controls naming more correct words in both categories.

Brosnan, Demetre, Hamill, Robson, Shepherd and Cody (2002) investigated the executive functions of organisation, planning, inhibition and sequencing in both adult and children with dyslexia, that are associated with the prefrontal cortex (e.g. Godfroy & Rousseaux, 1996; Shallice 1992; Goel & Grafman, 1995). Their adult sample of dyslexic participants consisted of individuals who were able to "compensate" for their deficits in reading and gain entry to higher education, whilst still having the underlying deficits of dyslexia. They used the group-embedded figures test (requiring participants to find a simple shape within a complex visual array shapes that are slightly different) to investigate the use of inhibitory processes. Brosnan et al. argue that the results suggested that the dyslexic group was significantly poorer at inhibiting the processing of contextual information. Thus, when the task demands were high they were not able to effectively inhibit the processing of the similar shapes to find the target shape from the distractor shapes. They also tested inhibition in children, finding that the dyslexic individuals were poorer on a digit span task that included verbal distractors in the form of background voices. This finding was argued to support a deficit in inhibiting the processing of contextual information; in this case the background voices. Brosnan et al. also found EF deficits in the executive functions of temporal order and verbal fluency. Individuals with dyslexia were significantly poorer than controls in a temporal order processing task involving identifying which picture was presented first from a series of 10 pictures originally shown to them. In the verbal fluency task the dyslexic group, in comparison to controls, showed deficits in generating as many words as possible that began with the letter "F" or "S" in one minute (excluding plurals and proper nouns). Brosnan et al. interpreted these finding as supporting a deficit in EF that is linked to the left prefrontal cortex. They argued that individuals use the right hemisphere to process stimuli in a global fashion whereas; the left hemisphere is more attuned to processing at a local level. In dyslexia Brosnan et al. argued that individuals with dyslexia are unable to inhibit distractors thus, they process globally instead of processing locally. This was reasoned to also account for the deficits seen in reading as they argue that individuals with dyslexia fail to inhibit distractors by using logographic processing (processing whole words) instead of processing the letters that are required for reading.

Research has also highlighted that individuals with dyslexia have reported a propensity to be disorganised which can be related to problems with EF in dyslexia (i.e. insufficient resources for planning or attentional processes/concentration). Smith-Spark, Fawcett, Nicolson and Fisk

(2004) administered the Cognitive Failures Questionnaires (CFQ; Broadbent, Cooper, Fitzgerald & Parkes, 1982) to dyslexics and controls. The CFQ investigated cognitive failures in questions such as item 2 “Do you find you forget why you went from one part of the house to the other?”, item 21 “Do you start doing one thing at home and get distracted into doing something else?” and item 22 “Do you find you can't quite remember something although it's on the tip of your tongue?”. In answering the self-report questionnaire, dyslexic participants rated themselves as having more cognitive failures in regards to slips of attention, language skills, planning and absent mindedness.

Smith-Spark et al. (2004) also corroborated these findings, by asking close friends or relatives to also report on the participant’s cognitive failures. They asked questions such as, if they found their friend/relative/housemate to be “disorganised, that is, getting into a muddle when doing something because of lack of planning or concentration”. The results found that the evidence of close friends or relatives supported the participant’s responses on the CFQ questionnaire, adding to the validity of the self-report questionnaire findings. This finding was supported by Leather, Hogh, Seiss and Everatt (2011) who were able to replicate Smith-Spark et al.’s (2004) findings, with the dyslexic individuals in their study demonstrating similar cognitive failures profiles. Levin (1990) undertook a study on 20 dyslexic children and 20 controls and found that children with dyslexia appeared to use less organised strategies in conceptual problem solving and in solving mazes, in comparison to controls. In looking at this issue from a different angle Kirby, Silvestri, Allingham and Parrila (2008) investigated the use of time management and study aids in post-secondary level education students. They found that students with dyslexia self-reported using more time management and study aids in comparison to controls. The authors have surmised several possible underlining reasons for these findings. They argued that use of these aids may be a result of specific word-level difficulties, a particular focus on support strategies that were devised as part of typical dyslexia support programmes or that it may be due to deficits in automating many of the processes utilised in the study and time management aids. McLoughlin, Leather & Stringer (2002) reviewed the characteristics of dyslexia and identified organisation and timekeeping inabilities as one of several primary features of dyslexia. Others have also supported these findings (e.g. Augur, 1985; McLoughlin, Fitzgibbon & Young, 1994; Tallal, 1985; Torgeson, 1977; Gilroy & Miles, 1996).

2.3. Summary

Traditionally, dyslexia has been thought to be underpinned by phonological deficits, however later research has revealed a range of deficits which are not linked to phonology. This chapter has shown that problems in dyslexia are not only related to difficulties in the acquisition of reading, writing or phonological skills (e.g. Snowling, 2000; Stanovich, 1988; Vellutino, 1979), but also to non-phonological processes such as allocation of attention (e.g. Nicolson & Fawcett, 1990; Fawcett & Nicolson, 1992) and executive functioning (e.g. Brosnan, Demetre, Hamill, Robson, Shepherd & Cody, 2002; Booth et al., 2010; Smith-Spark & Fisk, 2007). This chapter also outlined the broad range of cognitive deficits in dyslexia e.g. attention deficits, information processing, WM and EF impairments.

Chapter 3: Synthesis of prospective memory and dyslexia literature (rationale for prospective memory deficits in dyslexia)

This chapter is set out to synthesise the theories and processes relevant to both, prospective memory and dyslexia. The theories within both of these areas are discussed in relation to each other, pointing out areas that impact on PM that are also relevant in dyslexia. This establishes a clear rationale for the hypothesised deficits of PM in dyslexia and helps to understand the possible outcomes of different PM paradigms when given to participants with dyslexia compared to controls. This chapter explores also any possible overlaps between the processes involved in dyslexia and PM which may indicate PM deficits in dyslexia. Overall, this chapter provides a rationale for the hypothesised PM deficits in dyslexia.

3.1. Event-based prospective memory and dyslexia

3.1.1. Spontaneous retrieval vs. monitoring theories

Insufficient cognitive resources have previously been argued to be the underlying cause of worse task performance of individuals with dyslexia in comparison to typical population (e.g. Smith-Spark & Fisk, 2007). This was argued to be due to the inability to consciously compensate (CC) for task performance related deficits in difficult tasks (e.g. Nicolson and Fawcett, 1990). The spontaneous retrieval theory (Guynn, McDaniel & Einstein, 2001; McDaniel & Einstein, 2000; McDaniel et al., 2004) claimed that PM cues can trigger PM retrieval with no need for cognitive resources. This spontaneous retrieval of PM has been argued to be an automatic process, which does not rely on monitoring and does not produce cost to the ongoing activity. In line with this reasoning it is possible that event-based PM tasks may not result in event-based PM deficits in dyslexia, as they may be not difficult enough. Since event-based PM retrieval does not require cognitive resources, event-based PM tasks may not require cognitive resources to an extent that would exceed cognitive capacity available to individuals with dyslexia. This argument is in line with Nicolson and Fawcett (1990) who found that individuals with dyslexia are able to CC for performance deficits in less cognitively demanding (easier) tasks.

The claim that the retrieval of event-based PM intentions does not require additional cognitive resources is related to the argued lack of involvement of monitoring processes (Einstein et al., 2005), which have been reasoned to require cognitive resources (Burgess & Shallice, 1997). The point of view that no additional cognitive resources are required for event-based PM tasks as no monitoring is involved opposes the PAM theory (Smith, 2003) which claimed that event-based PM tasks always involve monitoring, thus utilising cognitive resources. On the basis of PAM theory it could be argued that all event-based PM tasks could produce difficult tasks conditions that draw on cognitive resources and this could result in event-based PM deficits in dyslexia. This is based on the reasoning that monitoring involved in event-based PM tasks together with the ongoing task demands would create cognitively demanding task conditions preventing individuals with dyslexia from CC and thus, result in PM deficit in dyslexia when compared to age and IQ matched controls. Even if the spontaneous retrieval theory is correct in assuming that no cognitive resources needed for retrieval of event-based PM, Marsh et al. (2008) argued that cognitive resources are needed for verification of PM cue (as shown by the slowing on the target trials). Following this logic one may support the reasoning that there may be event-based PM deficits dyslexia.

The reflexive-associative theory (e.g. Guynn et al., 2001) argued that whether the PM retrieval process will be automatic or not is depended on the quality of association formed between the PM cue and the intended action. Furthermore, the noticing plus search model (Einstein & McDaniel, 1996) reasoned that the spontaneous activation of retrieval of PM intention requires one to perceive the PM cue, which will in turn produce some internal response. The internal response was proposed to be the feeling of general familiarity with PM cue and this was claimed to be greater if the PM cue itself was used during the intention formation phase rather than just described in categorical terms. Thus, one could argue that if an event-based PM task shows participants the actual PM cues, it will produce greater internal response which could be argued to lead to an automatic spontaneous retrieval of the PM intention. On the contrary, a PM task which describes the PM cues without showing them to participants prior to the task, could be argued to rely on monitoring processes. This reasoning is similar to that of the multiprocess theory of PM (McDaniel & Einstein, 2000) which argued that focal event-based PM tasks are more likely to rely on spontaneous retrieval processes whereas the non-focal PM tasks will require monitoring processes.

3.1.1.1. Multiprocess theory of prospective memory and dyslexia

The multiprocess theory of PM (McDaniel & Einstein, 2000) claimed that focal event-based PM tasks involve automatic retrieval of the PM intention (spontaneous retrieval); whereas non-focal PM task are more likely to require conscious monitoring. This is linked to the debate concerning the involvement of cognitive resources in event-based PM tasks, with non-focal event-based PM tasks argued to involve more additional resources (Burgess & Shallice, 1997) for monitoring in comparison to focal PM tasks. Thus, on the basis of the multiprocess theory, it can be argued that it is more likely that event-based PM deficits will be found in non-focal PM tasks as opposed to focal designs, as non-focal PM designs are argued to involve additional cognitive resources. Non-focal event-based PM tasks could prove more demanding for individuals with dyslexia due to the involvement of monitoring processes that draw on limited cognitive resources. Therefore, on the basis of the multiprocess theory, one could argue for non-focal PM deficits in dyslexia due to the inability to consciously compensate for task related performance deficits. Nicolson and Fawcett (1990) found that individuals with dyslexia had task performance comparable to controls when easy tasks were employed and the same could be argued about focal PM tasks. Namely, that individuals with dyslexia will perform comparably to controls on a focal PM task. Nevertheless, if PAM theory (Smith, 2003) is correct and all event-based tasks require preparatory attentional processes, one could expect individuals with dyslexia to have problems on both focal and non-focal PM tasks.

It is also possible, that if all event-based PM tasks involve monitoring as reasoned by the PAM theory, both focal and non-focal PM tasks could result in slower responses to ongoing trials. Smith (2003) found that participants who were more accurate on the event-based PM component of the task were slower at responding to the ongoing trials compared to participants with poorer PM performance. The author suggested that this is related to a reduction of available attentional resources. Thus, if non-dyslexic individuals take longer to respond to ongoing trials when performing well on the PM trials due to insufficient attentional resources; it could be argued that individuals with dyslexia could experience even greater slowing on the ongoing trials in comparison to controls. If individuals with dyslexia are found to have significantly slower responses to the ongoing trials but still intact PM performance, this could be indicative of cognitive capacity deficits in dyslexia (e.g. Nicolson & Fawcett, 1990; Smith-Spark & Fisk, 2007). This supports Smith's (2003) argument that the slowing on the ongoing trials was a result of having to direct attentional capacity away from the ongoing task in order to successfully perform the event-based PM task.

3.1.1.1.1. Multiprocess theory, supervisory attentional system and dyslexia

The focal and non-focal event-based PM tasks identified by the multiprocess theory can be linked to the model of attentional control of action (Norman & Shallice, 1986). Namely focal event-based PM tasks, which rely on automatic (spontaneous) retrieval of PM, could be argued to be underpinned by a contention scheduling mechanism alone; whereas the non-focal PM tasks involving monitoring processes, which are non-automatic, could be reasoned to involve supervisory attentional system (SAS). Furthermore, monitoring processes have been also reported to draw on SAS/executive resources and SAS has been argued to be especially crucial for PM tasks which rely strongly on monitoring (Buggess & Sallice, 1997). In line with this reasoning Altgassen et al. (2014) found that that non-focal event-based PM tasks involve more attentional and WM resources in comparison to focal tasks. This is a plausible finding considering that the SAS has been proposed to be a candidate for the CE component of the WM model and similarly to the CE, it controls attention (Baddeley, 1986).

The argued involvement of SAS in non-focal PM tasks (due to its reliance on monitoring processes) is relevant to dyslexia and could indicate a non-focal PM deficit in dyslexia. In an alternative interpretation of results of a study conducted to investigate the DAD hypothesis, Nicolson and Fawcett (1990) stated that individuals with dyslexia have a problem with allocation of attention. Moreover, individuals with dyslexia have been argued to have SAS deficits (e.g. Smith-Spark & Fisk, 2007; Varvara et al., 2014). Smith-Spark and Fisk (2007) used SAS to explain the executive dysfunction found in dyslexia related to task novelty. Namely, they argued that the SAS is responsible for controlling non-automatic actions which are not well-learned or simple in nature. This description of a task resembles more a non-focal PM task compared to a focal PM task as non-focal PM tasks have been argued to rely on non-automatic monitoring. Furthermore, non-automatic tasks involving SAS require additional attentional and processing resources in order to control attention and thus non-focal tasks could be argue to be more difficult than focal tasks. Thus, on the basis of SAS deficits and difficulties with complex tasks reported in dyslexia, one could argue that individuals with dyslexia may demonstrate deficits in non-focal PM tasks.

More generally, the multiprocess theory has claimed that if ones WM resources are stretched, one is more likely to rely on spontaneous retrieval processes (McDaniel & Einstein, 2007). On the contrary, if one has WM resources available, this has been argued to result in the individual taking the monitoring approach to PM task performance. Considering that WM problems have been claimed to be the central characteristic of dyslexia (McLoughlin et al., 1994), one can argue that individuals with dyslexia are likely to rely on spontaneous retrieval processes even in non-focal PM tasks which have been argued to rely on monitoring. Thus the non-focal event-based PM performance of individuals with dyslexia could be affected negatively as monitoring processes have been suggested to improve PM performance (Smith, 2003).

3.1.1.1.2. The dynamic multiprocess framework and dyslexia

The dynamic multiprocess framework (Scullin et al., 2013) claimed that individuals will selectively engage in monitoring processes in event-based PM tasks when explicitly told to expect PM cues i.e. in a context in which a PM cue is expected. Thus, it can be reasoned that individuals with dyslexia may engage in cue monitoring behaviour in all event-based PM tasks if PM cues are expected. This could indicate PM problems in dyslexia in both, focal and non-focal PM tasks on the basis of the cognitive capacity related issues reported in dyslexia (e.g. Smith-Spark & Fisk, 2007).

3.1.2. Event-based prospective memory, executive functioning, and dyslexia

It was found that participants with high frontal lobe functioning were better at event-based PM tasks compared to these with low frontal functioning (McDaniel et al., 1995). Furthermore, a study conducted by Smith (2003, Experiment 3) investigating event-based PM found that individuals with low WM spans were less likely to respond correctly to event-based PM tasks compared to individuals with high WM spans. This suggests worse event-based PM performance in dyslexia compared to controls, as researchers reported WM deficits in dyslexia (e.g. Smith-Spark & Fisk, 2007). It was also argued that increased WM demands at the stage of retrieval of event-based PM intention have a negative impact on PM performance (Einstein et al., 1997). This is especially important in the cognitive resources debate in relation to individuals with dyslexia and when considering if they have a PM deficit. It has been claimed that some functions of the CE component of WM such as switching and inhibition (disengaging from one item in order to engage in another), have been found to extend the use of additional capacity by around 30% in comparison to control (Hari et al., 1999). Thus, one may argue that event-based PM tasks require additional cognitive resources apart from the capacity needed for performance of the ongoing or PM tasks. It therefore may be possible that due to this additional capacity requirement in PM tasks, the performance on the PM component of the PM tasks would result in lower accuracy in dyslexia compared to controls, due to dyslexia WM deficits.

Varvara et al. (2014) who found SAS/CE deficits in dyslexia argued that this was linked to visual attention deficit found in dyslexia and was in line with a deficit in automatic control of visual attention (e.g. Facoetti et al., 2003; cited in Varvara et al., 2014) and a deficit in rapid focussing of visual attention (e.g. Brannan & Williams, 1987; cited in Varvara et al., 2014). These deficits in visual attention in dyslexia could play out in event-based PM tasks which involve rapid focusing attention of ongoing and PM stimuli.

3.2. Executive functioning, prospective memory and dyslexia

3.2.1. Supervisory attentional system, working memory link to prospective memory and dyslexia

Varvara et al. (2014) argued that task complexity is responsible for poor task performance in dyslexia. Smith-Spark et al. (2003) explained that EF deficits argued in dyslexia and more specifically the domain general CE, results in significant drop of performance (compared to controls) if a task places a high demand on executive resources. Furthermore, Fawcett and Nicolson (1994) argued that complex skills which require fluency in component sub-skills, multi-modality skills involving the monitoring of various modalities/sources of information, skills which depend on time (and require fast speed of processing) and vigilance tasks which require concentration over time, are all vulnerable to disruption in individuals with dyslexia. Tasks involving these skills have been argued to create demands which prevent individuals with dyslexia from using CC to direct performance. These complex task conditions which are reported to result in performance deficits in dyslexia rely strongly on SAS/CE component of WM.

Prospective memory tasks have also been suggested to depend strongly on WM (e.g. Einstein et al., 2000). Marsh et al. (2002) found that PM performance dropped when ongoing tasks involved more WM. Martin et al. (2003) found that EF predicted time- and event-based PM performance. Burgess and Shallice (1997) stated that PM tasks involve SAS and that this is especially the case in tasks involving monitoring, as these tasks are argued to involve more cognitive resources compared to tasks relying on spontaneous retrieval. Thus complex PM paradigms which involve WM or SAS/CE (i.e. non-focal event-based, time-based or PM paradigms involving cognitively demanding ongoing tasks) could be argued to result in a poorer PM performance for individual with dyslexia than for controls. Since Smith-Spark et al. (2003) and Smith-Spark and Fisk (2007) argued that when task complexity is high, the CE or SAS of dyslexic individuals is unable to allocate extra resources to the task in order to consciously compensate for their EF deficit. This results in individuals with dyslexia performing worse compared to controls as their executive resources have been fully allocated to the task in hand. Thus, if a complex PM paradigm is used, one can expect a drop of performance visible either on the ongoing or the PM tasks in individuals with dyslexia compared to controls. Furthermore, one may argue that the switching of attention and inhibition of responses involved in event-based, as well as in the time-based PM tasks could adversely impact upon PM performance in individuals with dyslexia. This is in line with the argument that the SAS or the CE component of WM is responsible for attention switching and inhibition of responses (e.g. Norman & Shallice, 1986).

Moreover, one could argue that if a PM task involving monitoring (i.e. non-focal event-based or time-based PM) is combined with a cognitively demanding ongoing task, one could expect even more adverse effects on PM performance in individuals with dyslexia as these tasks would draw strongly on cognitive resources. This is hypothesised on the basis of WM/CE/SAS deficits in dyslexia (Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007). Additionally, global deficits in higher-order cognitive processes (EF) in developmental dyslexia (Smith-Spark & Fisk, 2007; Varvara et al., 2014) also support this hypothesis. Generally, it could be argued that the more complex the PM tasks, the greater the PM deficit will be as individuals with dyslexia would be less able to mask their performance deficits due to insufficient cognitive capacity (Nicolson & Fawcett, 1990).

3.2.2. Inhibition, switching involvement in prospective memory and its relevance to dyslexia

Another characteristic of PM tasks is that they require one to inhibit the performance on the ongoing task, in order to switch to the performance of PM task. This is an important aspect when considering possible PM deficits in dyslexia. Gonneaud et al. (2011) investigated the relationships between event- and time-based PM measures and a wide array of cognitive functions, including executive functions, processing speed, sustained attention, retrospective episodic memory, metamemory, and binding in healthy adults. This study found that regardless of whether the task used an event- or time-based PM paradigm, PM performance was dependent on inhibition abilities and processing speed. Furthermore, it was found that event-based PM was strongly reliant on binding and retrospective episodic memory and, to a lesser extent, on shifting, while time-based PM depended largely on inhibition.

Individuals with reading difficulties have been found to have problems with inhibition (e.g. Palladino et al., 2001; Swanson, 2006). In addition, Varvara et al. (2014) found that many tasks used in their research revealed poorer performance of dyslexics, due to deficits in inhibition which is one of the skills required for completion of these tasks e.g. their spoonerism task. Moreover, the SAS (which has been argued to be deficient in dyslexia) has been suggested to be responsible for interruption to the ongoing activity and shifting attention to the intended action at the appropriate time or when the PM cue appears (Einstein et al., 2005). Shifting abilities have been found to be a strong predictor of PM performance (Schnitzspahn et al., 2013). Hari and Renvall (2001) postulated that individuals with dyslexia have difficulty in switching between tasks, labelling this as sluggish attentional shifting. Dyslexics have been found to take longer to switch attention between a variety of tasks with Hari and Renvall (2001) arguing that they have difficulties disengaging from one stimulus in order to engage in another stimulus in sequentially presented tasks. Thus, this evidence could suggest that individuals with dyslexia may also have a general deficit in PM, as inhibition has been found to be linked to all types of PM in adults (e.g. Schnitzspan et al., 2013; Gonneaud et al., 2011).

Other researchers (e.g. Reiter et al., 2005) found that individuals with dyslexia only show deficits in inhibition in more cognitively demanding tasks. This again could point to dyslexia related PM problems, but only in cognitively demanding PM tasks such as, non-focal event-based or time-based PM tasks, as these involve monitoring or PM paradigms employing cognitively demanding ongoing tasks (e.g. involving WM updating). Brosnan et al. (2002) investigated EF in adults with dyslexia and found that when task demands were high, dyslexics were not able to effectively inhibit processing of similar shapes to find a target shape within a complex visual array shapes that are slightly different. This could be argued to mirror closely the principles used in event-based PM tasks, as one needs to inhibit processing the stimuli relevant to the ongoing tasks in order to find PM target cues placed within the array of the ongoing trial stimuli. Nonetheless, an event-based PM tasks could be argued to be easier and the stimuli could be argued to be more distinctive with the PM cues more obvious and jumping out at participants. Nevertheless, this piece of research shows that inhibition problems in adults with dyslexia could be relevant to all PM tasks. However, whilst all PM tasks have been said to involve inhibition, time-based PM tasks have been argued to involve inhibition to a greater extent (Gonneaud et al., 2011).

Studies (Swanson, 2006; Palladino et al., 2001) showed that individuals with dyslexia have problems in inhibition of irrelevant information or distractors and maintenance of relevant information in WM. This could indicate that individuals with dyslexia will have problems with inhibiting the irrelevant information related to ongoing task in order to perform the PM task. In addition, the deficit related to maintenance of relevant information in WM in dyslexia may be important in PM tasks which strongly involve WM (e.g. PM tasks involving WM updating ongoing tasks). Individuals with dyslexia may find it difficult to maintain the relevant information related to PM activity in WM in the presence of an ongoing activity which is highly competing for WM resources. This may stop individuals with dyslexia from recalling information relevant to the PM tasks or from self-initiating checking of the time. Furthermore, Borella et al. (2010) has explained that the inability to inhibit irrelevant information is linked to maintenance of irrelevant information in WM and that holding unnecessary information in WM results in WM overload. This may result in insufficient amount of WM resources left for the performance of the PM task in dyslexia.

3.2.3. Processing speed, prospective memory and dyslexia

Reiter et al. (2005) found that individuals with dyslexia have slower processing speed in inhibition tasks and this could indicate that individuals with dyslexia will have slower RTs in PM tasks, as these involve inhibition of the ongoing task in order to respond to the PM task. They also argued that individuals with dyslexia may need additional processing time in order to perform well on their EF tasks. Similar PM performance could be hypothesised in dyslexia as individuals with dyslexia may need additional time in PM tasks in order to perform well on them. Thus, if a time limit is applied to PM tasks, participants with dyslexia may respond less accurately. It is possible that individuals with dyslexia may feel the need to respond quicker than they would like to or can, and this could result in more errors in PM responses. On the other hand, if no time limit is applied, participants with dyslexia may take longer to respond correctly to the trials resulting in greater RTs.

This argument is in line with the processing speed deficit in dyslexia, which was established as a part of the double deficit hypothesis (especially when processing visual stimuli; e.g. Wolf and Bowers, 1999). Namely, if there is a processing deficit related to visual stimuli in individuals with dyslexia, one may expect individuals with dyslexia to be slower at recognising and processing PM cues in event-based PM tasks and in the ongoing tasks within all PM tasks. Thus, slower processing speed could impact negatively on PM performance in dyslexics. Gonneaud et al. (2011) have shown that processing speed correlated with event- and time-based PM performance in healthy adults. Namely, slower processing of the stimuli resulted in worse

PM performance and fast processing of stimuli resulted in better PM. Therefore any deficits in processing speed reported in dyslexia could have a negative impact on their PM performance. Furthermore, the “sluggish attentional shifting” found in dyslexia (Hari & Renvall, 2001) could be also used to support the claim that PM deficits will be found in dyslexia. It could be argued that the “sluggish attentional shifting” between the ongoing and PM tasks would result in worse PM performance. Thus, slower processing speed could be indicative of PM problems in dyslexia.

3.3. Time-based prospective memory and dyslexia

Gonneaud et al. (2011) highlighted the strong reliance of time-based PM tasks on inhibition. Thus, it can be expected that individuals with dyslexia may especially experience difficulties with time-based PM tasks due to the inhibition difficulties reported in dyslexia (e.g. Swanson, 2006). Furthermore, on the basis of the findings from Cockburn (1995), it could be predicted that time-based PM tasks, in which inhibition of the PM activity requires interruption of the ongoing activity, could be said to strongly engage participants’ attention and therefore are more likely to result in PM deficits in dyslexia, due to the limitations in attentional resources reported in dyslexia (e.g. Nicolson & Fawcett, 1990). Monitoring processes have been also argued to draw strongly on attentional resources and monitoring has been argued to be heavily involved in time-base PM tasks (Burgess & Shallice, 1997). In addition, Burges and Shallice suggested that monitoring relies strongly on the SAS. Considering SAS deficits in dyslexia, it is possible that individuals with dyslexia will have time-based PM problems. Moreover, individuals with dyslexia may not have enough resources for monitoring (in line with the CC hypothesis of Nicolson & Fawcett, 1990) in addition to the performance of the ongoing and PM tasks.

Time-based PM tasks have been argued to be more difficult than event-based PM tasks as they involve more self-initiation of the monitoring processes (e.g. Einstein & McDaniel, 1990; Groot et al., 2002). Thus, it could be argued that time-based PM processes may result in greater PM deficits in dyslexia compared to event-based PM. In support of the hypothesised time-based PM deficits in dyslexia, one can consider the age related deficits found in time-based PM tasks (e.g. d’Ydewalle, Luwel & Brunfaut, 1999; Martin & Schumann-Hengsteler, 2001). Even though ageing and dyslexia are two very distinct areas of study, researchers in both of these areas argued for the presence of attentional deficits. Since time-based PM performance involving monitoring processes is dependent on attentional resources (Burgess & Shallice, 1997) and deficits in attentional resources have been found in older adults (e.g. Craik & Byrd, 1982) and in individuals with dyslexia (e.g. Jeffries & Everatt, 2004; Smith-Spark et al., 2003), it is likely that individuals with dyslexia will also have poorer performances on time-based PM tasks.

Khan et al. (2008) found that high cognitive load resulted in significantly lower PM performance when compared to PM performance in tasks with low cognitive load. Basso et al. (2010) showed that ongoing tasks involving higher WM in time-based PM paradigm impacted negatively on PM performance and that WM and PM share resources but only in tasks involving high demands. This was reasoned to occur due to dividing attentional resources between the ongoing task, monitoring time and self-initiating the PM response at the required times. Khan and colleagues also suggested that monitoring of time is dependent on the limited resource of attentional capacity. Considering these arguments and the evidence of performance deficits in cognitively complex tasks and tasks involving WM in dyslexia (e.g. Smith-Spark & Fisk, 2007), it could be argued that time-based PM tasks involving high cognitive load / WM load are likely to result in time-based PM deficits in dyslexia.

McFarland and Glisky (2009) suggested that frontal lobes support self-initiated processing that is required for PM tasks. Burgess et al. (2001) found that PM task performance involves frontal lobe activation and monitoring based on PFC (Burgess et al., 2001). Okuda (2007) also identified that parts of rostral prefrontal are more active during time-based PM tasks compared to event-based tasks. Moreover, dividing attention over ongoing and PM task demands, switching and inhibition has been found to be impaired in frontal lobe patients and thus frontal lobe was argued to mediate these processes (e.g. Fuster, 1997). This could indicate that time-based PM tasks rely more on frontal lobe functioning and thus, individuals with dyslexia could be more likely to experience problems with time-base PM compared to event-based PM considering problems with frontal functioning in dyslexia (Swanson, 2006). This is in line with the reasoning that time-based PM tasks involve more monitoring processes as one needs to self-initiate checking of time compared to event-based PM tasks, which rely less on self-initiated processes (McDaniel & Einstein, 2007). Furthermore, Shimamura et al. (1991) reported that monitoring is controlled by prefrontal functioning. Moreover, McFarland and Glisky (2009) found that frontal lobe functioning predicted the quality of plans which their participants generated in order to assist PM performance, patterns of time monitoring and accuracy of time estimation. All of this could be argued to support the successful performance on time-based PM tasks. Thus, if individuals with dyslexia have problems making appropriate plans in order to perform the PM task or monitoring and estimating the time appropriately, due to frontal lobe functioning deficits, this may have a negative effect on their time-based PM performance.

One could also reason that time-based PM deficits could be found in dyslexia on the basis of the cerebellar deficit theory (Nicolson et al., 2001) as it linked time estimation deficits to dyslexia. Namely, it was argued that the cerebellum is responsible for time estimation and individuals with dyslexia were said to have a cerebellum deficit (Nicolson et al, 1995). This problem with time estimation in dyslexia could indicate time-based PM problems in dyslexia as time estimation is necessary in order to estimate the correct time for the initiation of checking the time, in order to perform the time-based PM tasks at the correct time.

3.4. Summary

In reviewing the literature on prospective memory and dyslexia, it appears that there is considerable evidence showing overlaps between the processes reported to underpin PM functioning and dyslexia deficits which points towards PM deficits in dyslexia, at least under certain conditions. These areas generally include a range of executive functions i.e. working memory (especially the CE component of WM; argued to play a similar function to the SAS), inhibition and task switching (e.g. Burgess & Shallice, 1997; Gonneaud et al., 2011; Hari & Renvall, 2001; Khan et al., 2008; Nicolson & Fawcett, 1990; Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007. Moreover, broadly speaking, EF processes as well as PM have both been associated with frontal cortical brain regions (e.g. Welsh, Pennington & Groisser, 1991; Burgess, Quayle & Frith, 2001).

The synthesis of the two bodies of literature is helpful in understanding which task conditions are more likely to show PM deficits in individuals with dyslexia. Some of the theories of event-based PM tasks in combination with dyslexia literature suggest event-based PM deficits, whereas on the basis of other theories the hypothesised event-based PM deficits in dyslexia are less clear. For instance, the PAM theory of PM (Smith, 2003) points towards event-based PM deficits in dyslexia whereas, in accordance with the spontaneous retrieval theory of PM (e.g. Einstein & McDaniel, 1996) one could argue that event-based PM deficits are less likely to occur in dyslexia. The multiprocess theory could indicate that PM deficits would be only found in dyslexia in non-focal event-based PM tasks but not in focal event-based PM paradigms. Nonetheless, in accordance with the PAM theory, it could be argued that focal PM tasks could still result in PM deficits in dyslexia. The synthesis of theories related to time-based PM and dyslexia could be said to suggest time-based PM deficits in dyslexia. Overall, it seems that cognitive capacity is the overarching factor playing a key function in the hypothesised PM deficits in dyslexia. Namely, individuals with dyslexia seem to have problems with tasks which place high demands on their cognitive resources and at least some PM tasks are argued to draw strongly on cognitive resources. Therefore, if can be argued that more cognitively demanding the PM paradigms (e.g. involving non-focal PM, time-based PM or complex ongoing tasks) are more likely to reveal the hypothesised PM deficits in dyslexia.

Having reviewed theories and processes related to both prospective memory and dyslexia there seem to be a plethora of evidence suggesting possible PM deficits in dyslexia at least under certain conditions. The empirical work carried out in this thesis sought to explore this hypothesis, using a variety of different methodological approaches.

Chapter 4: Self-report measures of PM

Prospective memory can be investigated in a number of different ways, by means of tests conducted under laboratory conditions, naturalistic studies and self-rated questionnaires (Maylor, 1993). Despite the majority of studies looking at PM using objective task measures, there is a growing body of research that has employed the use of self-reports of PM (e.g. Chan, Qing, Wu & Shum, 2010; Crawford, Smith, Maylor, Della Sala & Logie, 2003). There are a number of widely used and published questionnaires which probe into frequency of PM failures. These include the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie & Maylor, 2000), the Prospective Memory Questionnaire (PMQ; Hannon, Adams, Harrington, Fries-Dias & Gibson, 1995), the Comprehensive Assessment of Prospective Memory (CAPM; Roche, Moody, Szabo, Fleming & Shum, 2007) and the Time Cued Prospective Memory Questionnaire (TCPMQ; Cuttler & Graf, 2009). These questionnaires vary in regards to the different aspects of memory that they measure. For instance, the PRMQ investigates four different types of prospective as well as retrospective memory (RM) i.e. short-term, long-term, self-cued and environmentally-cued; whereas the PMQ not only investigates PM but also includes a subscale investigating the techniques people use to assist their memory e.g. the use of sticky notes as reminders. The CAPM questionnaire probes into basic and instrumental PM activities of daily living and is concerned with examining the reasons for PM failures, as well as the concerns that those failures may cause. The TCPMQ is focused on investigating time-cued PM, punctuality and memory aiding strategies. Initially, in this thesis, the PRMQ was used to investigate the frequency of self-reported PM failures.

4.1. Study 1: The Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Maylor, Della Sala & Logie, 2003)

4.1.1. Introduction

Questionnaires are widely used to investigate many psychological phenomena and provide information that no-one but the respondent knows (Baldwin, 2000). One of the positive aspects of using self-reports relates to the fact that they include the motives, goals, thoughts and emotions of a person rather than isolating them from the studied phenomenon (Reis, 2012). Conversely, self-reports can be criticised for being subjective in nature, especially when concerned with memory (Sunderland, 1990). Another difficulty with self-reports is that they require participants to answer questions about events that occurred in the past and therefore can be influenced by other factors e.g. beliefs or forgetting. This problem is referred to as retrospective bias (Reis, 2012). The retrospective bias occurs when past experiences are reconstructed inaccurately, as the influence of motivational and cognitive processes on memory can lower the accuracy of self-reports. There is a large variability with regards to the accuracy of self-reports when compared against objective criteria. A meta-analysis study conducted by Wentland and Smith (1993) revealed that the accuracy of surveys varied between 23 and 100% across a wide range of empirical studies testing, for example, language comprehension, memory and judgment.

Despite these criticisms, self-reports have become increasingly popular as they provide invaluable insight into phenomena that are difficult to measure empirically. More recently questionnaires have been used to study self-reported memory functioning and its relation to objective measures of memory (e.g. Kliegel, Zimprich & Eschen, 2005; Pearman & Storandt, 2004). The reliability of questionnaire data related to one's memory is often compared to data gathered from a close relative or friend of the participant, in order to check self-reported memory abilities (e.g. Broadbent, Cooper, Fitzgerald & Parkes, 1982; Smith-Spark, Fawcett, Nicolson & Fisk, 2004; Poliakoff & Smith-Spark, 2008). This, to some extent, corroborates the self-ratings of participants and extends the validity of the results.

The PRMQ (Smith et al., 2000) is a measure that investigates the frequency of failures related to PM and RM. It includes all other types of memory including episodic, semantic and procedural. Both the PM and RM measures are further subdivided into questions that probe short-term and long-term types of memory. This division is based on retention intervals. The short-term memory items are related to situations where the memory needs to be stored for a brief period of time before the recall of intention occurs e.g. remembering to take rubbish to the bin when leaving the house. Long-term memory items, on the other hand, refer to situations where a particular memory needs to be held in mind for a much longer time e.g. remembering to pass on a message to someone you will see one week later. The short- and long-term categories of PM and RM memory divide even further, forming sub-divisions of self-cued and environmentally-cued sub-types. These sub-division closely resembles the categorisation of time-based (self-cued) and event-based (environmentally-cued) tasks in PM (Einstein & McDaniel, 1990), but is still relevant to RM (Smith et al., 2000). Cues embedded in the environment do not require internal retrieval processes in order to be remembered successfully, unlike self-generated cues (Einstein & McDaniel, 2005). The PRMQ comprises of 16 items which form 8 pairs, with each pair corresponding to one of the eight aspects. These aspects will now be outlined. Prospective short-term self-cued items relate to memory intentions which need to be held in memory for short time intervals and rely on internal cuing. Prospective short-term environmentally-cued memory, on the other hand, relies on external reminders in the form of PM cues which need to be present in the environment. Similar principles apply to prospective long-term self-cued and prospective long-term environmentally-cued questions, but these two questions involve longer time intervals. There are also four retrospective scales which follow the same principles as the four PM scales described but these investigate memory for past events: retrospective short-term self-cued, retrospective short-term environmentally-cued, retrospective long-term self-cued and retrospective long-term environmentally-cued. The PRMQ has been used previously on a number of groups e.g. people with Alzheimer's Disease (Smith et al., 2000), individuals with multiple sclerosis (West, McNerney & Krauss, 2007), binge drinkers (Heffernan & O'Neill, 2012), smokers (Heffernan, O'Neill & Moss, 2010), people with schizophrenia (Chan, Wang, Ma, Hong, Yuan, Yu, Li, Shum & Gong, 2008) and patients with type II diabetes (Zahednezhada, Poursharifib & Babapourb, 2011).

It is important to consider the reliability and validity of the PRMQ as a tool for measuring self-reported PM abilities. Crawford, Smith, Maylor, Della-Sala and Logie (2003) stated that this tool is internally consistent and that the reliability of the PRMQ is very good (Cronbach's alpha for the total scale was 0.89: PM scale 0.84, RM scale 0.80). It has been proposed that the PRMQ has a potential advantage over other self-report scales, as it measures the constructs of prospective and retrospective memory systematically over a range of contexts (Crawford, Henry, Ward & Blake, 2006). Crawford et al. (2003) found the PRMQ total, prospective and retrospective scales to be highly reliable, arguing for a tripartite factor structure which includes general memory, prospective memory and retrospective memory. Research performed by Macan et al. (2010), Mantyla (2003), and Ronnlund, Mantyla and Nilsson (2008) reported that prospective and retrospective scores of the PRMQ are highly uncorrelated, with these findings further supporting the notion of a tripartite factor structure. In addition, Kiegel and Jager (2006) found that there was a significant difference between the PM and RM scores of PRMQ in the general population. Conversely, Uttl & Kibreab (2011) criticised the PRMQ for lacking divergent validity, as they argue that the prospective and retrospective subscales of the PRMQ are highly correlated and thus seem to measure similar constructs. This finding supports the idea that PRMQ is unidimensional (measuring memory in general, as one concept), as opposed to having a tripartite factor structure as stated by Crawford et al. (2003).

The general problem with self-reported measures of memory is that they do not always correlate highly with objective memory tests and clinical observations (Craik, Anderson, Kerr & Li, 1995). This has been found to be the case for PRMQ. A study conducted by Uttl and Kibreab (2011) found that the self-report version of PRMQ did not significantly correlate with objective, binary (discrete measures of success and failure) or continuous (presentation of memory cues at regular intervals) event based PM laboratory tasks (Uttl, 2008). The authors of this study also reported that the PRMQ does not correlate with a naturalistic time cued PM task. They concluded that the PRMQ has low validity and claimed that the reason for this is that the PRMQ relies on a non-objective 5-point scale (from never to very often) which requires participants to personally interpret the labels of these scales. Rabbitt, Maylor, McInnes, Bent and Moore (1995) claimed that if a participant interprets the label in relation to peers they know, this may create a false self-report. Namely, if one thinks that one does not experience many PM failures compared to known peers, one may report them to occur rarely, when in fact they may be making frequent errors in comparison to the wider population. Contrary to the evidence that PRMQ does not predict actual PM performance, Kliegel and Jager (2006) found that objective PM performance was predicted by self-reported PRMQ scores. Their findings showed that the PM subscale was a significant predictor for time-based PM performance and approaching significance for event-based PM performance under laboratory conditions. This study also supported the previously argued multidimensionality of the PRMQ. Since the RM subscale of the PRMQ, as well as the PRMQ total did not predict objective PM ability (just the PM subscale did) and thus indicated that PM and RM are separate concepts. The lack of correlation between RM subscale and objective PM task performance found by Kiegel and Jäger (2006) is consistent with the evidence of Macan et al. (2010), Mantyla (2003), and Ronnlund, Mantyla and Nilsson (2008) and supports the claim that PRMQ is at least bi-dimensional as it involves prospective and retrospective dimensions.

Therefore, the literature related to PRMQ reliability and its usefulness in predicting actual PM ability under laboratory controlled conditions is mixed. Nevertheless, there is more evidence supporting its validity and reliability (e.g. Crawford et al., 2003). There is considerably less research which investigates the predictability of naturalistic PM tasks based on self-reports of PM. In addition, when considering whether the PM component of PRMQ can predict the actual PM performance, a proxy-rating version of PRMQ in which close friends or relatives of the participant rate can provide a useful tool. The proxy-rating version of PRMQ was used in initial studies conducted by Smith et al. (2000) and Crawford et al. (2003), who claimed that the proxy-rating version of the PRMQ is potentially more useful in research than the self-rated version. Since individuals' beliefs about their own memory may not always resemble actual memory performance, as insight into their abilities may be limited (Herrmann, 1984), especially for those whose memory problems occurred as a consequence of brain injury (Crawford et. al., 2006). Thus proxy ratings may be a more valid way of investigating PRMQ reliability. On the contrary, one's beliefs about one's own memory abilities can influence actual memory performance (Hannon et al., 1995).

The PRMQ has been also used in an investigation correlating self-reported PM abilities and time management in the general population by Macan, Gibson and Cunningham (2010). Their study found that people who report that they manage time well and have a strategy for organisation and prioritisation, also reported successful prospective and retrospective memory. Such effective behaviours stand in contrast to these reported in the dyslexia literature where individuals with dyslexia report themselves to be disorganised (Smith-Spark et al., 2004), have planning difficulties (e.g. Levin, 1990; Torgeson, 1977; Gilroy & Miles, 1996), or organisation and timekeeping inabilities (e.g. Augur, 1985; McLoughlin, Fitzgibbon & Young, 1994; Miles, 1982; Tallal, 1985; Turner, 1997). Therefore, based on Macan et al.'s (2010) study, which found a positive correlation between organisation and PM in the general population, it is possible that individuals with dyslexia who have difficulties with time management, organisation and planning may also show deficits in PM .

To the best knowledge of the author, there are no studies that have used questionnaires to investigate PM in adults with developmental dyslexia. However, a study conducted by Smith-Spark et al. (2004) investigating everyday cognitive failures in adults with developmental dyslexia, touched upon PM problems in dyslexia. This study, using the Cognitive Failures Questionnaires (CFQ; Broadbent, Cooper, Fitzgerald & Parkes, 1982), found significant differences in everyday cognitive functioning between dyslexic adults and age and IQ-matched control participants. Smith, Della Sala, Logie and Maylor (2000) identified two CFQ items that address PM. Namely, item 16 "Do you find you forget appointments? and item 23 "Do you find you forget what you came to the shops to buy?", draw on memory for future intentions. These two questions would seem to clearly investigate PM as they ask about the frequency of forgetting to perform intended actions that were to be carried out after a certain amount of time has elapsed. In addition, item 2 of the CFQ may be argued to also include a PM component. Even though item 2 "Do you find you forget why you went from one part of the house to the other?" has previously been classified as investigating distractibility (Smith-Spark et al., 2004), it can be argued to also include elements of prospective and retrospective memory. Specifically, being able to recollect the intended activity when getting to other part of the house forms the PM component (Dobbs & Rule, 1987; Einstein & McDaniel, 1996); whereas remembering the contents of the intention is the retrospective part (Graf & Uttl, 2001). Smith-Spark et al. reported that the former two CFQ questions (16 and 23) resulted in highly significant differences between dyslexic and controls. It was found that individuals with dyslexia reported experiencing significantly more cognitive lapses related to PM when compared to age and IQ-matched controls. On the basis of these two items, it can be concluded that adults with dyslexia perceived themselves to be significantly weaker, when it comes to PM. Furthermore, the results from Smith-Spark et al. (2004) were replicated recently by Leather, Hogh, Seiss and Everatt (2011). In order to explore PM difficulties in dyslexia further and more definitively, the PRMQ was used to investigate PM in individuals with dyslexia compared to age- and IQ-matched individuals without dyslexia. It was predicted that the results would be consistent with the findings in Smith-Spark et al.'s (2004) study of wider everyday cognitive performance, with individuals with dyslexia reporting deficits.

The anecdotal and empirical evidence (e.g. Augur, 1985; Gilroy & Miles, 1996; Levin, 1990; McLoughlin, Fitzgibbon & Young, 1994; Miles, 1982; Tallal, 1985; Turner, 1997; Torgeson, 1977) suggests that less effective PM will be reported by individuals with dyslexia compared to adults without dyslexia. On the basis of this literature it was hypothesised that individuals with developmental dyslexia would report more frequent occurrences of PM failures compared to age- and IQ-matched controls. The PRMQ was, therefore, used to investigate self-reported abilities of PM within dyslexic and non-dyslexic groups. However, to extend the validity of the PRMQ self-reported measure used within this study the PRMQ was also adapted to be administered also to close friends or relatives of participants taking part in this study to seek confirmation of these reports. It was thought that a proxy-rating version of PRMQ would be useful in the current investigation as it would provide a more balanced view in regards to the frequency of memory failures of participants. This was similar to the check performed by Smith-Spark et al. (2004) using two CFQs (one for participants, one for significant others), that were originally developed by Broadbent et al. (1982). In Smith-Spark et al's. (2004) study the results from CFQ-for-others corroborated the results acquired from CFQ. Therefore, it was also hypothesised that the reports of close friends or relatives of dyslexic individuals would corroborate any self-reported deficit of prospective and retrospective memory in dyslexia. For the purpose of this thesis the focus was on the PM component of the PRMQ rather than on the RM component, as literature pointed towards PM problems in dyslexia (e.g. Smith-Spark et al., 2004).

4.1.2 Method

4.1.2.1. Participants

4.1.2.1.1. General participant matching procedure

In order to investigate whether there were any deficits in the cognitive skills of participants with developmental dyslexia it was important to compare their cognitive skills to the skills of individuals without developmental dyslexia through the use of a comparison group. This approach allowed a comparison between the two participant groups (participants with and without dyslexia) in relation to possible differences in PM. Goswami (2003) argued that these two participant groups need to be matched for chronological age and IQ in order to rule out the possibility of the results being affected by these differences. For this reason a short-form IQ measure (Turner, 1997) was used. This was comprised of the Comprehension, Block Design, Similarities and Picture Completion sub-tests from the WAIS-IV (Wechsler, 2008), used previously by Smith-Spark et al. (2003; 2004) and Smith-Spark and Fisk (2007). This short-form IQ measure (Turner, 1997) was used because none of its sub-tests are sensitive to the presence of dyslexia, thus providing a fair comparison of the intellectual abilities of the two groups. The calculation of abbreviated IQ measure was based on scaled scores and followed the principles stated by Turner (1997). All participants who scored below 90 on this short-form IQ measure were removed in order to minimise the possibility that the results could be explained by lower ranges of IQ (see, e.g. Fawcett and Nicolson, 1990; 2004).

All of the dyslexic participants reported having dyslexia and were asked to provide dyslexia reports from educational psychologists (based at government-approved diagnostic centres) in order to verify the diagnosis of dyslexia. Likewise, the non-dyslexic individuals declared that they did not have a prior diagnosis of dyslexia. Nicolson and Fawcett (1997) found that self-reports of being non-dyslexic are highly accurate. In addition to this each participant was assessed on two literacy screening measures. The Nonsense Passage Reading subtest from the Dyslexia Adult Screening Test (DAST; Fawcett & Nicolson, 1998) was used to estimate the fluency (based on time taken to read the passage) and accuracy of reading a mixture of real words and orthographically legal nonwords (nonsense words). The speed and accuracy of reading the nonsense passages are sensitive to the presence of dyslexia and show deficits even in dyslexics who are able to consciously compensate (Brachacki, Fawcett & Nicolson, 1994; Finucci, Guthrie, Childs, Abbey & Childs, 1976; Hatcher & Snowling, 2006).

In the Nonsense Passage Reading subtest, points are deducted for incorrectly pronounced or missed words. One bonus point is awarded for every 2 seconds below the time mark of 60 seconds (for completing the passage) and 1 point is taken away for every 2 seconds over the 60 seconds time limit. This procedure was followed in all of the studies carried out in the current thesis. In addition, participants without dyslexia who scored below 88 were removed from the sample as it is possible that these individuals could be dyslexic (in accordance with Nicolson & Fawcett's 1997 norms).

The second dyslexia screening task investigated spelling ability using the spelling component of the Wechsler (1993) Objective Reading Dimensions (WORD). The WORD spelling task comprised of 50 words which increased in the difficulty during the task. The first 20 words of the test were omitted as the participant group was comprised of adults. This test discontinues after 6 consecutive errors. Each participant was given the credit for the 20 omitted words plus the number of correctly spelled words. This formed the basis of spelling age for each of the participants. Control participants who did not reach the total of 42 points in this task were removed from the sample as they did not reach the adult spelling range (score equal to or more than 42).

These two measures (Nonsense Passage Reading and WORD) assessing reading and spelling abilities provide a strong indicator of the presence of dyslexia and have been used extensively within the literature for similar purposes (e.g. Bacon, Parmentier & Barr, 2013; Smith-Spark et al., 2003; 2004; Smith-Spark & Fisk, 2007). Each study described in this thesis used the same criteria and t-tests were used in order to check if the two participant groups were matched for IQ and to differentiate the two participant groups on literacy measures. The descriptive statistics and t-tests comparing the two participant groups on literacy (after removing controls showing literacy characteristics not in the adult range) and short-form IQ measures are shown in each study separately as the groups of participants differed between some of the studies. Participants in each study within this thesis met the same stringent criteria for inclusion.

4.1.2.1.2. Participants (Study 1)

Data were collected from two groups of participants: university students (N = 54) with and without dyslexia. All of the participants were native English speakers and aged between 18 and

35 years. A total of 28 individuals with dyslexia and 26 without dyslexia were recruited. The descriptive statistics (mean, SD and range for age and gender split) are included in Table 1.

Unrelated t-tests were used in order to check if the two participant groups were matched for IQ and to differentiate the two participant groups on literacy measures. The descriptive statistics and unrelated t-tests comparing the two participant groups on literacy and short-form IQ measures can be also seen in Table 1.

Table 1: Descriptive statistics for gender and age and t-tests performed on literacy screening measures and short-form IQ.

	Measure										
	Gender		*Age (years)*		WORD Spelling Age	WORD Spelling Raw Score		DAST NWR Score		WAIS-IV Short-form IQ	
Group	Male	Female	Mean	SD	N<17 years	Mean	SD	Mean	SD	Mean	SD
Controls (N = 26)	6	20	23.31	4.63	0	44.77	1.73	92.35	3.25	107.34	9.47
Dyslexics (N = 28)	5	23	23.82	4.14	19	40.21	3.76	77.21	11.48	107.32	7.63

Independent samples t-test

WORD Spelling Raw Score *t*	*df*	*p*	DAST NWR Score *t*	*df*	*p*	WAIS-IV Short-form IQ *t*	*df*	*p*
5.77	38.44	< .001	6.69	31.60	< .001	.009	52	.993

Further to this, data were collected from close friends or relatives of participants with and without dyslexia. The group of close friends or relatives (N = 50) who rated the PM of participants were recruited through the participants themselves. The rate of non-return for the PRMQ-for-others was N = 4 (three from the dyslexic group and one from control group).

4.1.2.1.3. Materials

The Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Maylor, Della-Sala, Logie and Maylor, 2000) was used. This questionnaire consisted of 16-items allowing participants to rate the frequency of different types of memory errors, by means of 5-point scales: Very Often = 5, Quiet Often = 4, Sometimes = 3, Rarely = 2 and Never = 1. Half of these questions related to PM and the other half to RM. Each of these eight questions contained two items related to short-term self-cued type, short-term environmentally cued, long-term self-cued and long-term environmentally cued. The instructions, order and scoring system employed were the same as in the original PRMQ (Smith et al., 2000).

The wording of the introduction and questions of the PRMQ administered to the relative or close friend of a participant were changed appropriately. The introduction was similar to the original but stated that these questions were about the close friend or relative from which the questionnaire was received. To avoid any confusion, the name of the participant who was to be rated by close friend or relative was written next to the instructions paragraph where it explained that these questions were about a close friend or relative. The questions themselves were changed to emphasise that the questions were not about the respondents themselves but about their close friend or relative e.g. “Does your close friend or relative decide to do something in a few minutes’ time and then forgets to do it?”

4.1.2.1.4. Design

A multivariate analysis of variance (MANOVA) was used, with participant group (dyslexic versus controls) as the independent variable and type of memory (prospective short-term self-cued, prospective short-term environmentally-cued, prospective long-term self-cued, prospective long-term environmentally-cued, retrospective short-term self-cued, retrospective short-term environmentally-cued, retrospective long-term self-cued and retrospective long-term environmentally-cued) as the dependent variables. The dependent variables in this study were measured on the basis of the ratings expressing the frequencies of everyday memory failures, with higher scores equating to more frequent errors. In addition, unrelated t-tests were used to test for differences in means of the dyslexic group and non-dyslexic group on total PRMQ, prospective and retrospective scores. The same multivariate analysis of variance (MANOVA) and unrelated t-tests were applied to the scores on the PRMQ-for-others.

4.1.2.1.5. Procedure

Informed consent was acquired from all participants prior to testing. Background information about participants (age, gender and dyslexia status) was collected before administration of the short-form IQ and literacy measures. After completion of these measures participants were asked to complete the PRMQ. The instructions provided to participants were the same as in the original PRMQ (Smith et al., 2000) and included a statement that the questions were about minor memory mistakes which everyone makes from time to time, but some of which happen more often than others. Participants were then asked to indicate how often different memory failures happened to them by ticking the appropriate place on the scale and were instructed to answer all of the questions, even if they did not seem entirely applicable to their situation. All responses were treated confidentially. Participants were asked to fill in the questionnaires about themselves in a quiet area within the laboratory.

Participants were also given a questionnaire (covering questions about the participant), to take with them and asked to give it to a close friend or relative for them to complete. The wording of the instructions of the PRMQ-for-others administered to a relative or close friend of a participant explained that the questions were about the close friend or relative from which they had received the questionnaire. Participants were asked to return the questionnaires from their friends or relatives in person or via the post (stamped addressed envelopes were provided). Participants were debriefed at the end of the study.

4.1.2.2. Results

4.1.2.2.1. The PRMQ

Several members of the control group (N = 6) were removed from the data set and replaced due to showing literacy characteristics not in the adult range. There were also participants (N = 7, 3 dyslexic and 4 control participants) who were removed from the study due to short-form IQ scores below 90. Individuals with dyslexia reported, on average, more memory errors, both prospective and retrospective compared to controls. The means for the two participant groups and t-tests are present in Table 2.

The results from the unrelated t-tests carried out on the total PRMQ, prospective and retrospective scores revealed significant differences between the groups in the frequency of prospective memory failures.

Table 2: Descriptive statistics and unrelated t-tests for total PRMQ, Prospective and Retrospective scales.

Scale	Controls (N = 26)	Dyslexics (N = 28)	*Unrelated t-test*		
			t	*df*	*p*
Total PRMQ score	37.77 (SD = 8.32)	51.11 (SD = 11.60)	4.82	52	< .001
Prospective score	20.00 (SD = 4.57)	27.14 (SD = 6.60)	4.59	52	< .001
Retrospective score	17.77 (SD = 4.45)	23.96 (SD = 5.52)	4.52	52	< .001

Note. Differences on all of the scales were statistically significant at the Bonferroni corrected alpha level of .017.

A multivariate analysis of variance (MANOVA) was conducted on the eight different subscales of the PRMQ The one-way MANOVA indicated that group membership had a significant multivariate effect on memory, F (8, 45) = 3.33, p = .005, Wilks' Lambda = .63, partial $\eta 2$ = .372. Power to detect the effect was .948. Follow-up univariate F-tests indicated that group membership significantly affected all of the memory types. The dyslexic individuals reported all types of memory failures to be significantly more frequent compared to controls. The F-statistics for the follow-up univariate ANOVAs are displayed in Table 3.

Table 3: Descriptive statistics and univariate ANOVA for the eight PRMQ subscales.

Scale	Controls (N = 26)	Dyslexics (N = 28)	ANOVA		
			F (1, 52)	*p*	η_p^2
Prospective short-term self-cued	2.85 (SD = .75)	3.57 (SD = .88)	10.61	.002	.170
Prospective short-term environmentally-cued	2.54 (SD = .71)	3.52 (SD = 1.03)	16.94	< .001	.246
Prospective long-term self-cued	2.31 (SD = .74)	3.34 (SD = .95)	19.60	< .001	.274
Prospective long-term environmentally-cued	2.31 (SD = .57)	3.14 (SD = 1.03)	13.41	.001	.205
Retrospective short-term self-cued	2.73 (SD = .79)	3.66 (SD = .85)	17.25	< .001	.249
Retrospective short-term environmentally-cued	1.73 (SD = .47)	2.50 (SD = .90)	15.02	< .001	.224
Retrospective long-term self-cued	2.15 (SD = .75)	3.07 (SD = .98)	14.85	< .001	.222
Retrospective long-term environmentally-cued	2.27 (SD = .72)	2.75 (SD = .80)	5.34	.025	.093

Note. Higher scores indicate poorer memory.

4.1.2.2.2. The PRMQ for close friends or relatives (PRMQ-for-others)

The results from the unrelated t-tests carried out on the total PRMQ-for-others and its prospective and retrospective components supported the results from total PRMQ and its prospective and retrospective scales. There were significant differences in the frequency of memory failures of participants with dyslexia and without dyslexia as reported by their close friends or relatives, even when Bonferroni corrected alpha levels of .017 were applied. Close friends or relatives of participants indicated that on average, participants with dyslexia made significantly more memory (prospective and retrospective) errors compared to participants without dyslexia. The means for the two samples and unrelated t-tests are present in Table 4.

Table 4: Descriptive statistics and unrelated t-tests for total PRMQ-for-others and its Prospective and Retrospective scales.

Scale	Controls (N = 24)	Dyslexics (N = 26)	*Unrelated t-test*		
			t	*df*	*p*
Total PRMQ score	33.50 (SD = 5.77)	44.00 (SD = 11.52)	4.12	37.43	< .001
Prospective score	15.96 (SD = 3.56)	20.08 (SD = 6.16)	2.92	40.58	.006
Retrospective score	17.54 (SD = 3.56)	23.93 (SD = 6.65)	4.28	38.90	< .001

Note. All of the scales were statistically significant at the Bonferroni corrected alpha level of .017.

The same analysis was performed on the PRMQ-for-others data. The multivariate analysis of variance (MANOVA) revealed a significant multivariate effect of group membership on memory, F (8, 41) = 2.71, p = .017, Wilks' Lambda = .65, partial $\eta 2$ = .346. Power to detect the effect was .880. Follow-up univariate F-tests indicated that group membership significantly affected all the subscales except the retrospective long-term self-cued and retrospective long-term environmentally-cued memory types. The F-statistics for the follow-up univatiate ANOVA are displayed in Table 5.

Table 5: Descriptive statistics and ANOVA for PRMQ-for-others, Prospective and Retrospective totals as well as for the eight subscales.

Scale	Controls (N = 24)	Dyslexics (N = 26)	ANOVA		
			F (1, 48)	*p*	η_p^2
Prospective short-term self-cued	2.21 (SD = .62)	2.96 (SD = .88)	11.96	.001	.199
Prospective short-term environmentally-cued	2.42 (SD = .75)	3.04 (SD = .92)	6.85	.012	.125
Prospective long-term self-cued	2.08 (SD = .60)	2.94 (SD = .88)	16.07	< .001	.251
Prospective long-term environmentally-cued	2.06 (SD = .47)	3.02 (SD = 1.09)	15.71	< .001	.247
Retrospective short-term self-cued	2.31 (SD = .64)	3.12 (SD = 1.07)	9.64	.003	.167
Retrospective short-term environmentally-cued	1.63 (SD = .56)	2.06 (SD = .62)	6.68	.013	.122
Retrospective long-term self-cued	1.94 (SD = .65)	2.33 (SD = .97)	2.74	.104	.054
Retrospective long-term environmentally-cued	2.10 (SD = .55)	2.54 (SD = .96)	3.77	.058	.073

Note. Higher scores indicate poorer memory.

4.1.2.3. Discussion

The results showed that individuals with dyslexia perceived themselves as being more prone to prospective and retrospective memory failures than age- and IQ-matched controls. This applied to all types of prospective and retrospective memory, regardless of whether it involved short or long time intervals between intention formation and intention execution, or whether it was self- or environmentally-cued. The results from the subscales of PRMQ-for-others revealed significant group differences on the short-term self- and environmentally-cued retrospective memory scales. That is, close friends or relatives of participants with dyslexia judged them to experience significantly more retrospective memory failures which involve short-term time interval that are either cued by the environment or internally. These findings supported the results from PRMQ. However, contrary to the self-ratings of participants, their close friends and relatives reported that individuals with dyslexia do not display any abnormality when it comes to long-term environmentally- and self-cued retrospective memory. This may be because deficits in long-term retrospective memory are not as evident to outside observers in comparison to the short-term retrospective memory failures. It may be easier for a close friend or relative to verify more recent past events in the participant's life than these occurring over longer time periods.

In addition, the largest effect size (η_p^2) in both questionnaires (the PRMQ and PRMQ-for-others) was for the prospective long-term self-cued type of memory. Self-cued PM can be argued to be related to time-based PM as both of these rely on self-initiated remembering to perform the PM task. On the other hand, environmentally-cued PM is more relevant to event-based PM as both of these types rely on external cues to act as a reminder to perform the PM tasks. Time-based PM tasks have been found to require more self-initiated monitoring than event-based tasks (Einstein & McDaniel, 1990). According to Koriat, Ben-Zur and Nussbaum (1990) time-based tasks are more difficult to perform as they require more internal monitoring processes. Thus, PM tasks which are self-cued can be considered to be more cognitively demanding in comparison to tasks which are environmentally-cued and involve less self-initiated processes. In addition, holding PM intentions in memory becomes more difficult as the time intervals increase. The largest size effects found, using the PRMQ and PRMQ-for-others for the prospective long-term self-cued memory, support Nicolson and Fawcett's (1990) theory (described in more detail in Chapter 2) which claims that the more difficult the task, the more evident the cognitive deficits will be in individuals with dyslexia.

The retrospective memory scales of the PRMQ showed that dyslexic adults rated themselves as having significantly more retrospective memory failures (all types) compared to control participants. These findings are supported by earlier findings from a study conducted by McNamara and Wong (2003) looking at children with learning disabilities (LD) which included students with dyslexia. This study showed that children with LD performed poorly in their recall of everyday information. In McNamara and Wong's dance episode task, which required students to recall information retrospectively after five weeks from the episode (a dance workshop), children with LD were able to recall 26% of the dance episode questions. This was poor compared to children without LD matched for chronological age who recalled 66% of the dance episode questions. The authors concluded that it is possible that students with LD were able to recall only 26% of the dance episode information due to a difficulty in accessing the relevant information from their long-term memory. It has been also proposed that this finding could be caused by a memory processing problem experienced by students with LD. Another task used in McNamara and Wong (2003) investigated retrospective recall of information related to procedural task involving library checkout procedures. In this task students with LD were also less able to recall information related to library checkout procedures retrospectively: 49% for children with LD and 99% for children without LD. This investigation showed also that students with LD recalled significantly less procedural information compared to students without LD. It has been proposed by the authors of this study that students with LD may have retrieval problems which affect the ability to recall procedural information. Therefore, it may be possible that students with dyslexia reported themselves to have significantly more retrospective as well as PM problems due to a problem with retrieving retrospective information. Namely, dyslexic individuals could be inaccurate when self-reporting both retrospective and PM failures due to the memory retrieval deficiency proposed by McNamara and Wong (2003). The memory retrieval difficulties could also be used to explain the poor metacognitive awareness of individuals with dyslexia, as it may be difficult to be aware of the performance of ones own cognitive processes such as memory, if one has difficulties accessing information from memory about ones own performance in the past.

It is also possible that individuals with dyslexia reported themselves as having significantly more memory problems due to low self-esteem. Humphrey (2002) found that many studies report children with dyslexia as having lower self-esteem and self-concept. In addition, Alexander-Passe (2006) found that sixth form college students with dyslexia reported lower self-esteem. A study conducted by Riddick, Sterling, Farmer and Morgan (1999) investigating dyslexia among university students using past and present educational histories provided by students found that individuals with dyslexia reported lower levels of self-esteem. Kleitman and Stankov (2007) have found self-confidence to correlate moderately (.41) with metacognitive processes in the general population. This study suggested that confidence is related to metacognitive awareness. It is therefore recommended that future studies include self-esteem measures to tease apart the possibility that either the low self-esteem reported by individuals with dyslexia or that the combination of low self-esteem and poor metacognitive awareness could have resulted in low self-ratings on the PRMQ scales. However, the combination of low self-esteem and poor metacognitive awareness cannot explain the differences found using the PRMQ-for-others. Similarly to the results from the PRMQ, the PRMQ-for-others total score, as well as PM and RM scores revealed that individuals with dyslexia are perceived, by relatives and close friends, as having significantly higher frequency of PM and RM failures.

The evidence obtained in this study is consistent with the results of Smith-Spark et al. (2004) which touched upon PM in adults with dyslexia. The two CFQ items investigating PM found that individuals with dyslexia self-rated their own PM lapses to be significantly more frequent than of IQ-matched controls. Those findings are in line with the current data collected by the means of PRMQ and PRMQ-for-others which found that individuals with dyslexia and their significant others, reported significantly more frequently PM failures compared to controls. This provides a first indicator of a PM deficit in the population of adults with developmental dyslexia and is an original contribution to the literature. There are no published studies that investigate the frequency of self-reported, everyday PM failures in the population of adults with developmental dyslexia age- and IQ-matched controls.

The results obtained from the PRMQ and PRMQ-for-others are consistent with the argument that individuals with dyslexia are more disorganised (Smith-Spark et al., 2004) or have planning difficulties (e.g. Levin, 1990; Torgeson, 1977; Gilroy & Miles, 1996), organisation and time keeping inabilities (e.g. Augur, 1985; McLoughlin et al., 1994; Miles, 1982; Tallal, 1985; Turner, 1997). A study conducted by Macan et al. (2010) may support this further. They found a correlation between self-reported PM abilities and time management in the general population. Individuals who self-reported good time management skills also have strategies for organisation and prioritisation. Furthermore, they also indicated that their PM was good. Therefore, if one has a poor time management abilities, ones PM scores should reflect this with poorer performances. As individuals with dyslexia rated themselves to be significantly worse on all PRMQ subscales within this current study, Macan et al. (2010) findings, suggest this group should exhibit problems with PM performance.

4.2. Study 2: The Prospective Memory Questionnaire (PMQ; Hannon, Adams, Harrington, Fries-Dias & Gibson, 1995)

4.2.1. Introduction

An additional self-reported measure of the frequency of PM failures in everyday life was administered to adults with developmental dyslexia and controls, who were matched for age and IQ. The Prospective Memory Questionnaire (PMQ; Hannon et al, 1995) was used as a further self-reported measure of PM, in order to investigate the techniques individuals may use to assist their PM. In contrast to the PRMQ, the PMQ does not include any environmentally-cued PM items. Environmentally- cued PM relate to event-based PM, the investigation of which formed a large part of this thesis. It was therefore seemed beneficial to use both questionnaires (PRMQ and PMQ) to complement each other, as the PRMQ includes items related to environmentally-cued PM whereas the PMQ has a section looking at memory aiding techniques. Using both questionnaires would provide a fuller picture of the self-perceptions of PM processes in adults with dyslexia.

An initial study involving the PMQ reported that this self-rating of PM is internally consistent (Hannon et al., 1995). The test-retest reliability was also reported to be high (.88). The authors of the PMQ found that PMQ has a weak, but significant correlation with short-term PM tasks and a non-significant correlation with long term PM tasks. This finding supports the statement of Herrmann (1984) which concluded that self-reports of memory usually produce low associations with actual performance. Nevertheless, the PMQ has been widely used as a measure of self-reported frequency of everyday PM failures on a range of populations e.g. to compare PM of smokers to non-smokers (Heffernan, Ling, Parrott, Buchanan, Scholey & Rodgers, 2005); recreational Ecstasy uses to Ecstasy-free controls (Heffernan, Jarvis, Rodgers, Scholey & Ling, 2001; Montgomery & Fisk, 2007) and excessive alcohol users to low-dose/non-users of alcohol (Heffernan, Ling & Bartholomew, 2004).

The techniques to assist memory subscale of the PMQ (PMQ TECH) investigates the use of memory aiding strategies. The aiding strategies include planning, making use of rehearsal and using reminders e.g. sticky notes. These items assess the frequency with which participants use different types of memory aiding strategies. The PMQ also consists of three other subscales. Namely, the long-term episodic subscale (PMQ LTE), the short-term habitual subscale (PMQ STM) and the internally cued subscale (PMQ IC). The latter three subscales investigate the frequency of PM failures. The long-term episodic memory subscale refers to memory intentions which need to be held in memory for an extended number of hours or days before they can be executed and occur rarely, e.g. forgetting to send a postcard for a birthday. The short-term habitual subscale refers to tasks which occur regularly and involve short time intervals between intention formation and its execution, e.g. forgetting to button some part of clothing when dressing. The internally cued subscale comprises questions related to tasks which rely solely on internal memory. This means that there are no external PM cues acting as a reminder to perform the intended PM activity e.g. one may forget what he or she wanted to say in the middle of a sentence. Items from this subscale are related to the time-based PM paradigm.

The PMQ was administered to adults with developmental dyslexia and controls to investigate PM and the use of memory aiding strategies. It was predicted that individuals with dyslexia would report more frequent use of memory aiding techniques compared to controls. This in turn would support the evidence from Study 1 (the PRMQ) as this would also suggest poorer self-reported PM. That is, if participants with dyslexia report using memory aiding strategies more frequently, this could indicate an awareness of impairment of the relevant internal processes responsible for reminding oneself about the intended action. In addition, individuals with dyslexia were hypothesised to report more strategies for aiding PM based on Nicolson and Fawcett (1990) who claimed that individuals with dyslexia use coping strategies to compensate for their cognitive deficit. In this case, using more strategies for memory aiding would be a coping strategy helping individuals with dyslexia to compensate for and mask their PM deficit.

4.2.2. Method

4.2.2.1. Participants

There were two groups of participants, adults with developmental dyslexia and controls matched for age and IQ. The selection criteria for participants were the same as in Study 1 (PRMQ). Descriptive statistics regarding the gender and age of participants can be found in Table 6. The descriptive statistics and t-tests comparing the two participant groups with regards to IQ and the literacy measures can be seen in Table 6.

Table 6: Descriptive statistics for gender and age and t-tests on literacy screening measures and short-form IQ.

	Measure											
	Gender		*Age (years)*		WORD Spelling Age	WORD Spelling Raw Score		DAST NWR Score		WAIS-IV Short-form IQ		
Group	Male	Female	Mean	SD	N<17 years	Mean	SD	Mean	SD	Mean	SD	
Controls (N = 26)	4	22	24.46	5.31	0	45.12	1.80	93.00	3.01	107.27	8.84	
Dyslexics (N = 25)	7	18	24.44	3.80	12	41.44	3.72	80.32	11.39	110.59	9.18	

Independent samples t-test

	WORD Spelling Raw Score			DAST NWR Score			WAIS-IV Short-form IQ		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
	4.47	34.31	< .001	5.39	27.21	< .001	1.31	49	.195

4.2.2.2. Materials

The PMQ consists of 52 items spread across four timescales, over which participants gauged performance. The long-term episodic memory subscale, made up of 14 questions, referred to memory intentions which need to be held in memory for an extended number of hours or days, before they can be executed and do not occur frequently. The questions within this subscale include questions such as “I missed appointments I had scheduled”. The short-term habitual subscale, also consisted of 14 questions, and referred to tasks which occur regularly and involve short-time intervals between intention formation and its execution e.g. “I forgot to lock the door when leaving my apartment or house”. The internally cued subscale comprised of 10 questions regarding PM tasks which have no external cues acting as reminders e.g. “I was driving and temporarily forgot where I was going”. The techniques to assist memory subscale of PMQ (PMQ TECH) consisted of 14 questions that investigated the use of memory aiding strategies. These included questions about planning, making use of rehearsal and reminders e.g. “I write myself reminder notes”. The first three subscales investigated the frequency with which participants encountered PM failures in a week, month or year prior to testing (depending on the question). The fourth subscale investigated the frequency of use of memory aiding techniques and used the week as the unit of time. Visual analogue scales with descriptors (never, two, four or more times) were used, as in the original PMQ study (Hannon et al., 1995). A “not applicable” option was also provided for each question. The order in which the questions were presented and the scoring system followed the original PMQ (Hannon et al., 1995) format. The mean score for each subscale was calculated on the basis of average for all items. Higher scores indicated more PM failures.

4.2.2.3. Design

A multivariate analysis of variance (MANOVA) was used, with participant group (dyslexic versus controls) as the independent variable and type of memory (long-term episodic, short-term habitual, internally cued and techniques to assist memory) as the dependent variables. The dependent variables in this study were measured on the basis of the ratings expressing frequencies of everyday memory failures (where higher scores indicated more frequent failures). In addition, an unrelated t-test was used to test for differences in means of the dyslexic sample and non-dyslexic sample on total PMQ scores.

4.2.2.4. Procedure

Informed consent was acquired from all participants prior to testing. Participants were instructed to familiarise themselves with the instructions that showed two example responses. Participants were told that if they feel that the question did not apply to them they could circle the N/A option. The attention of participants was brought to changing temporal descriptors below each question (week, month or year). The remaining procedure was the same as specified in Study 1 (PRMQ). Participants were debriefed at the end of the study.

4.2.3. Results

A multivariate analysis of variance (MANOVA) was conducted using the long-term episodic, short-term habitual, internally cued and techniques to assist memory subscales of PMQ. The multivariate test (one-way MANOVA) indicated that group membership had a significant effect on self-reports of memory, F (4, 46) = 3.81, p = .009, Wilks' Lambda = .751, partial $\eta 2$ = .249. Power to detect the effect was .859. Follow-up univariate F-tests indicated that group membership significantly affected the long-term episodic and internally cued memory types. Dyslexic individuals reported these types of memory failures to be significantly more frequent compared to controls. The follow-up univariate F-tests also indicated that group membership significantly affected the frequency of use of techniques to assist memory. Individuals with dyslexia reported using significantly more of these techniques which aid memory significantly more frequently than controls. It was also found that group membership had no significant effect on the short-term habitual memory type.

The results of the unrelated t-test carried out on the total PMQ scores revealed significant differences between the frequencies of memory failures. Individuals with dyslexia reported, on average, significantly more PM errors compared to controls. The means for the two samples, follow-up F-tests and t-test are present in Table 7.

Table 7: Descriptive statistics, follow-up univariate ANOVAs and t-test for PMQ.

Scale	Controls (N = 26)	Dyslexics (N = 25)	ANOVA		
			F (1, 49)	*p*	η_p^2
Long-Term Episodic	1.97 (SD = .93)	2.95 (SD = 1.75)	6.35	.015	.115
Short-Term Habitual	.46 (SD = .49)	.77 (SD = 1.00)	1.99	.165	.039
Internally Cued	2.56 (SD = 1.26)	4.18 (SD = 2.10)	11.31	.002	.187
Techniques to Assist Memory	2.89 (SD = 1.41)	3.98 (SD = 1.78)	5.91	.019	.108
			Unrelated t-test		
			t	*df*	*p*
Total PMQ score	1.96 (SD = .77)	2.99 (SD = 1.15)	3.73	41.71	.001

Note. Higher scores indicate poorer memory, but in the Techniques to Assist Memory scale higher scores indicate more frequent use of techniques used to aid memory (reminders, rehearsal and planning). The Total PMQ score is an average from Long-Term Episodic, Short-Term Habitual and Internally Cued subscales.

4.2.4. Discussion

The results of this study support those of Study 1. Namely, individuals with dyslexia reported that they experienced significantly more everyday PM failures compared to controls matched for age and IQ. The subscales of the PMQ also revealed that the long-term episodic, the internally cued and the techniques to assist memory subscales of PMQ yielded significant differences between the two samples, whereas the short-term habitual subscale showed no differences. The internally cued subscale produced the largest effect size (η_p^2) indicating that this type of PM, which relies on the participant to provide internal cuing in order to remember to perform the PM activity, is rated the most difficult by participants with dyslexia relative to controls. Individuals with dyslexia also reported a problem with PM in circumstances where the PM intention needed to be held in memory for longer periods of time e.g. doing something in one week’s time. In addition, the results revealed that individuals with dyslexia reported a PM deficit in situations where the PM activity does not occur frequently e.g. once or rarely. However, there was no significant difference between the self-ratings of the two groups when it came to events that occur frequently e.g. every day. The findings are in line with the claims of Smith-Spark and Fisk (2007), who suggested that adults with dyslexia find it significantly more difficult to respond to novel action sequences. Smith-Spark and Fisk explained the difficulty with novel action responses in individuals with dyslexia was due to a SAS (Norman & Shallice, 1986) deficit. The SAS is responsible for controlling non-automatic novel actions. Thus, habitual PM which occurs frequently is not controlled by SAS, as it is likely to be an automatic process (once schemas are set up). Conversely, the episodic PM is less likely to be well-learned and automatic, as it occurs rarely and therefore can be argued to draw on SAS. Thus, the results from the PMQ support the findings that individuals with dyslexia reported themselves to have problems with long-term episodic PM, but not with the short-term habitual PM.

Martin et al. (2003) found that frontal/executive functions are related to PM performance in a range of PM paradigms. Furthermore, they found that EF predicted PM performance on complex standard tests of PM. Internally cued PM activities require one to self-initiate the retrieval of an intended action compared to externally cued PM tasks, which are triggered by PM cues embedded within the environment. In order to self-initiate the retrieval of an intended action, it is argued that one needs to engage more internal monitoring processes (Einstein & McDaniel, 1990). Koriat et al. (1990) stated that tasks which require more internal monitoring processes are more difficult to perform. Therefore, it can be claimed that the SAS may also be involved in the performance of internally cued PM activities relying on executive processes as the SAS is responsible for tasks which are not simple. Thus, the findings of Smith-Spark and Fisk (2007) suggesting the SAS/EF deficit in individuals with dyslexia are further supported by the results from the internally cued PM subscale of the PMQ, since individuals with dyslexia reported to have significantly more internally cued PM failures. Similar to EF deficits found in poor PM performance (Martin et al., 2003), Brosnan et al. (2002) and Reiter et al. (2005) found executive function deficits in organisation, planning, inhibition and sequencing in individuals with dyslexia. The self-reported deficits identified by the dyslexic group in the PMQ TECH subscale support the evidence of EF deficits in relation to planning that was found in research by Martin et al. (2003) and Brosnan et al. (2002).

The discussion in Chapter 1 related to the automatic and self-initiated processes underpinning PM, is also relevant to the findings of the current study. Internally cued PM activities require one to self-initiate the retrieval of intended action compared to externally cued PM tasks, which are triggered by PM cues embedded within the environment (Einstein & McDaniel, 1990). Therefore, internally cued PM activities, those most closely related to time-based PM, rely on self-cuing where self-initiated monitoring of the environment is triggered by the individual. However, externally cued PM tasks (event-based PM tasks with focal targets) rely on automatic processes, where an external PM cue acts as a reminder to perform the intended action (McDaniel & Einstein, 2000). The internally cued PM tasks are more cognitively demanding than externally cued PM tasks, as one needs to use ones cognitive capacity to constantly monitor for the appropriate moment to perform the intended action. Thus, the self-reported deficit found in the current study in relation to internally cued PM in dyslexics, is in line with Nicolson and Fawcett's (1990) conclusion that individuals with dyslexia are unable to mask their deficits in performance when tasks are more cognitively demanding. It can be argued that the deficit found in dyslexics, on the basis of the internally cued subscale of the PMQ, is also in line with the conscious compensation (CC) hypothesis of Nicolson and Fawcett. Since the results showed that individuals with dyslexia found this type of PM the most difficult (reflected in the greatest effect size) and thus, it can be claimed that individuals with dyslexia were less able to consciously compensate for their PM deficit, as task demands may have extended beyond their cognitive capacities. It is plausible to suggest that individuals with dyslexia show a larger deficit on cognitively demanding PM tasks and therefore reported having a perceived deficit of internally cued PM, as this type of PM is more cognitively demanding. Moreover, the fact that there was also a large effect size for the long-term episodic subscale and a small effect size for the short-term habitual subscale further supports this assumption related to cognitive load. Namely, it could be suggested that having to remember to perform a PM activity which occurs frequently it is less cognitively demanding compared to one that occurs rarely.

The PMQ was also used in order to provide an insight into differences in the degree individuals with and without dyslexia believe that they externalise their cognition. The results from the "techniques to assist memory subscale" of the PMQ not only suggest that there is a potential problem with PM in individuals with dyslexia, but also indicates the use of coping strategies by dyslexics, in order to avoid everyday PM failures. Individuals with dyslexia reported using more memory aiding strategies such as making explicit plans, rehearsing PM activities to be performed in future, and using external reminders compared to controls. It may be the awareness of problem with PM that leads individuals with dyslexia to use more memory aiding strategies to avoid them. Nevertheless, it could be suggested that individuals with dyslexia seem to not use the memory aiding strategies (which they reported to use more frequently) efficiently as they still have reported more PM problems. Future research is recommended in order to gain insight to the effectiveness of memory aiding stratifies in dyslexia and possible support mechanisms that could support individuals with dyslexia in the workplace.

4.3. Summary

In summary, the findings from this chapter, acquired by means of the PRMQ and a proxy-rating version of the PRMQ revealed a perceived deficit of PM in adults with developmental dyslexia compared to age and IQ-matched controls. The findings from the PMQ confirmed the PM deficit found using the PRMQ and indicated that internally-cued (time-based) and long-term episodic types of PM may be more problematic for individuals with dyslexia than short-term habitual type of PM. In addition, the PMQ showed that individuals with dyslexia rely more frequently on techniques to aid memory when remembering prospectively when compared to controls. This is in line with empirical evidence showing EF deficits in planning and organising.

The results therefore indicated that PM deficits might be empirically observable in dyslexia and the next step is the investigation to see whether the self-reported differences in PM actually play out in actual deficits in performance. This was explored in Study 3, using a clinical measure of PM.

Chapter 5: Performance on a clinical measure of prospective memory

5.1. Study 3: Memory for Intentions Screening Test (MIST)

5.1.1. Introduction

The next stage of the research investigation involved probing whether the self-reported differences in PM between adults with dyslexia and age- and IQ-matched controls would actually play out in objective measures of PM. A well-established clinical measure of PM, the Memory for Intentions Screening Test (MIST; Raskin, 2004) was therefore used as an initial, exploratory measure of actual PM performance. The MIST has been widely used to investigate PM in a range of populations such as individuals with HIV (Poquette, Moore, Gouaux, Morgan, Grant & Woods, 2013), people with schizophrenia (Woods, Twamley, Dawson, Narvaez & Jeste, 2007) and ecstasy users (Weinborn, Woods, Nulsen & Park, 2011). Given that the MIST is an established clinical measure supported by a substantial body of literature and is used extensively in the field of PM, it was deemed appropriate to use the MIST as a first step in the objective measurement of PM in adults with developmental dyslexia before creating bespoke computer-based PM tasks. While it should be noted that the MIST provides a relatively blunt measure of PM as it is aimed at clinical populations (e.g. Poquette et al., 2013), the MIST should nevertheless, indicate whether individuals with dyslexia have PM deficits and, if they do, point to the specific types of PM problems experienced by them.

The MIST comprises of eight PM tasks (plus a naturalistic PM task with a 24-hour delay) and an ongoing task (a word search puzzle). The eight PM tasks form six scales. Two of the scales are related to the difference in time interval between intention formation and intention execution and include two different short-term time intervals (2- and 15-minutes). There are also two scales differentiating between time- and event-based PM cue. The type of response required from participants is investigated by two scales whether a verbal or action response is needed. The verbal type of response requires participants to verbally execute the PM intention whereas in an action response participants must initiate an action in order to execute the PM intention. The score from each of the eight PM tasks contributes to three scales of the MIST. For example, a PM task informing participants to self-address an envelope when the experimenter hands it to them (2 minutes after giving the instruction) is an event-based task, which requires an action response involving a 2-minute time interval. Another example could be a task where participants are asked to remind the experimenter to check his or her mail in 15 minutes. This task would therefore contribute scores to the time-based, verbal response and 15-minutes interval scales. The MIST also contains an optional time-based naturalistic task which involves asking participants to initiate a PM activity 24 hours after the PM instruction was provided. The reliability (e.g. Raskin, 2009; Woods, Moran, Dawson, Carey, Grant et al., 2008) and construct validity (e.g. Raskin & Buckheit, 2001; Woods, Dawson, Weber, Gibson, Grant & Atkinson, 2009) of the MIST has been supported within the literature.

The MIST employs multiple different PM tasks which overlap with each other i.e. there are multiple intentions which need to be held in memory at the same time, while performing the ongoing task or PM tasks. This characteristic of MIST was used as an initial investigation into the effect of PM load on PM performance. Basso et al. (2010) found that PM load has a negative effect on PM performance. Basso and colleagues also argued that proficient PM performance depends on WM resources, in tasks involving high demands. This is in line with the literature which shows the negative effect of high WM load on PM performance, especially if the CE is affected (e.g. Einstein et al., 1997; Marsh & Hicks, 1998). Marsh et al. (2002) found that PM performance diminished when the ongoing task engaged more WM resources. Marsh and colleagues claimed that PM tasks are affected by WM load as they involve the coordination of both the ongoing task and the PM task and that this process involves executive control. With multiple intentions needing to be held in memory whilst the ongoing task is performed, the ongoing or PM tasks in MIST can be argued to involve WM. Working memory is responsible for actively holding multiple pieces of information and manipulation of these information (Crowder, 2013). Thus, it was hypothesised that performance on PM tasks which require participants to hold multiple PM intentions (high PM load) while being engaged in the ongoing task will result in worse performance compared to PM tasks which only involve holding one or two PM intentions at the time (low PM load). Furthermore, because individuals with dyslexia have been argued to have deficits in CE/WM (e.g. Smith-Spark & Fisk, 2007), it was hypothesised that the high PM load will have a negative effect on the PM performance of individuals with dyslexia.

It could be also argued that individuals with dyslexia will display difficulties with time-based PM, as they may not have enough WM resources available for monitoring the time in addition to performing the ongoing task whilst having to hold other PM intentions in memory. This reasoning is in line with Nicolson and Fawcett (1990) DAD/CC hypothesis, as it could be claimed that the insufficient WM resources could prevent individuals with dyslexia from consciously compensating for their PM deficit. However, Nicolson and Fawcett (1990) used a dual-task paradigm where children were required to perform two tasks at once. The difference between the PM tasks and classic dual-task paradigm is that in PM tasks one needs to stop performing an ongoing task in order to engage in PM task whereas in classic dual-task paradigm one needs to perform both tasks simultaneously. The hypothesised problems with time-based PM are also in line with the results from Study 2 (PMQ) where individuals with dyslexia rated themselves as experiencing more frequent time-based PM failures in comparison to controls.

Nevertheless, regardless of PM load and PM type, it was hypothesised that individuals with dyslexia will have a worse PM performance compared to age- and IQ-matched control participants, as all of the PM tasks used in the MIST involve inhibition of the ongoing task responses and task switching, which have been found to be deficient in dyslexia (e.g. Hari & Renvall, 2001; see Chapter 2). This is also in line with the results from Study 1 (PRMQ) which revealed event- and time-based self-reported PM deficits in dyslexia.

5.1.2. Method

5.1.2.1. Participants

The same participants as in Study 2 were used in this study (see Study 2 participant section for participant characteristics).

5.1.2.2. Materials

This study utilised the version B from the MIST kit (MIST; Raskin, 2004) and included the optional time-based naturalistic task which involves a 24 hour delay. Each of the six scales (time-based, event-based, verbal, action, 2- and 15-minutes) is formed of four PM tasks that contribute scores to its total. Each PM task can be scored from 0 to 2 depending on performance where the score of 2 indicates correctly performed PM task. Therefore, the total score from each scale can range from 0 to 8. The maximum overall MIST score is 48. For the complete instructions regarding scoring please see Raskin (2009) and Woods et al. (2008).

The MIST also provides standardised error coding instructions. There are five types of errors which can be coded for the eight PM tasks. These are: no response (when no PM response is made), task sublimation (when an action response is replaced with a verbal response or vice versa; or when any prior response is performed instead of the correct response; or when the participant performs a novel response), loss of content (the participant indicated that they had to provide a response but cannot remember the content), loss of time (the participant performs the correct response but at the incorrect time i.e. more than or less than one minute from the appropriate execution time) and random error (incorrect responses which cannot be coded as previous errors).

The word search puzzle (Form B) as well as a large digital clock included with the MIST comprehensive kit were used. A checklist which comprised of multiple choice recognition items was used to check whether PM failures were due to encoding (retrospective) or retrieval (prospective) failure. This checklist, administered on completion of the eight PM tasks, comprised of eight questions each with three possible answers e.g. “At any time during this test, were you supposed to: 1) tell me to make an appointment; 2) tell me when I can call you tomorrow; 3) tell me to call for a prescription”.

The optional time-based naturalistic task involving a 24 hour delay was also administered to participants. The 24 hour delayed task required participants to leave a voicemail message for the experimenter reporting their name and the number of hours they had slept that night. This activity was to be performed exactly 24 hours after the instruction was given to participants. Therefore, a landline telephone number with an answering machine system was required. A university extension was used for this purpose. There was a standardised message on the answering machine with the option to leave a message after the tone. The scoring followed the original MIST guidelines where no points were given to participants who did not leave a voicemail, one point to those who left a voicemail but did not remember the correct content of the message (i.e. the number of hours slept) and two points for participants who left the voicemail message with the correct content within one hour of the required time either side (2 hours’ time window).

5.1.2.3. Design

A multivariate analysis of variance (MANOVA) was used, with participant group (dyslexic versus control) as the independent variable and types of memory (time-based, event-based, 2-minutes, 15-minutes, action response and verbal response) as the dependent variables. The dependent variables in this study were scores obtained by participants on the basis of their performance on the PM tasks which formed the six PM scales.

Unrelated samples t-test analysis was applied to test for differences in means of the dyslexic sample and non-dyslexic sample on the total MIST score, the ongoing task total (word search puzzle), the retrospective recognition questionnaire total and the 24 hours delayed task. Higher raw scores on these measures indicated better PM performance.

The sum of each of the five types of errors (no response, task sublimation, loss of content, loss of time and random error) made by each participant was analysed using one-way MANOVA in order to investigate whether there were any differences between the two participant groups.

A further mixed measures ANOVA was conducted with participant group as the between-subjects factor (levels of treatment: dyslexic and control participants) and memory load as the within-subjects factor (levels of treatment: low and high memory load). The low memory load consisted of the mean score for PM tasks six, seven and eight whereas the high memory load was taken from the mean scores for PM tasks one, two, three and four. The memory load clusters have been established on the basis of the information from the original MIST kit (Raskin, 2004) and were based on the number of instructions/tasks participants had to remember at once. The low memory load condition included PM tasks which required participants to hold one or two PM intentions in memory. The high memory load condition comprised of PM tasks where participants had to hold four or five different PM intentions in memory at the same time.

5.1.2.4. Procedure

Informed consent was acquired from all participants prior to testing. Background information about participants (age, gender and dyslexia status) were collected before administration of the short-form IQ and literacy measures. The MIST measure was administered at the end of the testing session after completion of the PMQ questionnaire. Participants were asked to sit at a desk with a large digital watch in a visible position. The experimenter sat on the other side of the desk but not directly facing the participant. Each participant heard the standardised MIST instructions and had an opportunity to ask any questions and clarify the instructions if needed. After this, the participant engaged in the word search puzzle (the ongoing task) for the duration of the test (30 minutes). While working on the word search puzzle, participants heard eight standardised PM instructions at different times during the testing session lasting for 30 minutes. When the required time or cue appeared, participants had to perform a certain action or provide a certain verbal response. For example, participants heard the instruction to tell the experimenter in two minutes time, the time that they could be called tomorrow. When the two minutes had elapsed participants were required to stop the word search puzzle and tell the experimenter the suitable time to be called e.g. “you can call me tomorrow at 2pm”.

After completing the eight MIST PM tasks participants were asked the questions from the multiple choice recognition checklist. They were asked to select the correct response from three possible answers. At the end, participants were given the instructions to perform the delayed PM task. The experimenter’s telephone number was given to participants verbally and each participant was asked to save the telephone number directly into their mobile phone contacts to avoid any paper notes which could act as reminders. For the complete description of the MIST administration procedures please see Raskin (2009) and Woods et al. (2008). Participants were debriefed at the end of the study.

5.1.3. Results

5.1.3.1. MIST scales

An independent samples t-test carried out on the total MIST score (out of 48) revealed that participants with dyslexia (M = 42.20, SD = 6.71) did not differ significantly compared to controls (M = 44.58, SD = 4.20), t (49) = 1.52, p =.134.

A multivariate analysis of variance (MANOVA) was conducted using the six different scales of the MIST investigating 2- and 15-minutes time delay, time- and event-based types of PM, as well as PM memory involving verbal and action responses. The multivariate test (one-way MANOVA) indicated that group membership had a non-significant effect on memory, F (6, 44) = .915, p = .493, Wilks’ Lambda = .889, partial $\eta 2$ = .111. Power to detect the effect was .322.

Even though the MANOVA was not significant, the results of the follow-up univariate F-tests were included, as the MIST is a “blunt” measure that is designed to be used for clinical samples and this bluntness may be reflected in the low power (despite N in the typical range for studies of cognition in dyslexia). Therefore, the univariate results were unpacked further for exploratory purposes. The follow-up univariate F-tests indicated that group membership significantly affected PM tasks with time-based cues and PM tasks requiring verbal responses. Individuals with dyslexia scored significantly lower on the time-based PM tasks and PM tasks requiring verbal responses compared to controls. However, group membership had no significant univariate effect on the 2- and 15-minute scales nor on the event cue and action response scales. The descriptive and F-statistics for the follow-up univariate ANOVAs are displayed in Table 8.

Table 8: Descriptive statistics and follow-up univariate ANOVAs conducted on MIST measures.

Scale	Controls (N = 26)	Dyslexics (N = 25)	*F* (1, 49)	ANOVA *p*	η_p^2
2-Minute Time Delay score	7.96 (SD = .20	7.64 (SD = 1.08)	2.25	.140	.044
15-Minute Time Delay score	6.92 (SD = 1.26)	6.32 (SD = 1.82)	1.90	.174	.037
Time Cue score	7.19 (SD = 1.13)	6.40 (SD = 1.63)	4.08	.049	.077
Event Cue score	7.69 (SD = .74)	7.68 (SD = .95)	.003	.959	< .001
Verbal Response score	7.65 (SD = .63)	7.16 (SD = .99)	4.58	.037	.086
Action Response score	7.23 (SD = 1.03)	7.00 (SD = 1.47)	.423	.518	.009

5.1.3.2. Ongoing task

An independent samples t-test performed on the ongoing task (word search puzzle) showed that there was no significant difference between participants with dyslexia (M = 32.80, SD = 6.16) and without dyslexia (M = 35.15, SD = 7.78), t (49) = 1.20, p =.238.

5.1.3.3. Memory errors

A multivariate analysis of variance (MANOVA) was conducted using the frequency of the five types of PM errors (no response, task sublimation, loss of content, loss of time and random errors). The multivariate test (one-way MANOVA) indicated that group membership had a non-significant effect on the number of PM errors, F (4, 46) = 2.35, p = .068, Wilks' Lambda = .830, partial η2 = .170. Power to detect the effect was .634.

The univariate results of the error data were unpacked further for explanatory purposes, given that the F-value was close to significance. The follow-up univariate F-tests of the numbers of different types of errors revealed non-significant differences on no response, task sublimation and loss of content errors. There were no random errors reported by either of the participant groups. The results from loss of time error were close to significance (p = .051) and indicated that individuals with dyslexia made more PM errors when they performed the correct task, but at the incorrect time i.e. more than or less than 1min from the appropriate execution time. The descriptive and F-statistics for the follow-up univariate ANOVAs are displayed in Table 9.

Table 9: Descriptive statistics and follow-up univariate ANOVAs conducted on PM errors.

Scale	Controls (N = 26)	Dyslexics (N = 25)	F (4, 46)	ANOVA p	η_p^2
Errors					
No response	.077 (SD = .39)	.360 (SD = .76)	2.84	.098	.055
Task sublimation	.50 (SD = .76)	.40 (SD = .58)	.278	.601	.006
Loss of content	.192 (SD = .40)	.320 (SD = .56)	.887	.351	.018
Loss of time	.038 (SD = .20)	.320 (SD = .69)	3.99	.051	.075

5.1.3.4. Memory Load

To investigate further the effect of memory load (low and high) on the two participant groups, a mixed measures ANOVA was conducted. The results revealed a significant main effect of memory load F (1, 49) = 7.38, p = .009, η_p^2 = .131. This main effect of memory load revealed that all participants had lower PM scores in PM tasks involving a high memory load condition, compared to the low memory load condition, which resulted in higher PM scores. There was also a significant main effect of participant group F (1, 49) = 4.09, p = .049**,** η_p^2 = .077. The main effect of participant group showed that individuals with dyslexia had significantly lower PM scores compared to controls across the two memory load conditions. However, there was no significant interaction F (1, 49) = .154, p = .697, η_p^2 = .003.

5.1.3.5. Retrospective recognition questionnaire

An independent samples t-test was used to analyse the retrospective recognition questionnaire total scores (out of 8) for the two participant groups. The results showed that there was no significant difference between participants with dyslexia (*M* = 7.96, *SD* = .20) and without dyslexia (*M* = 7.96, *SD* = .20), *t* (49) = .028, *p* =.978.

5.1.3.6. Naturalistic time-based delayed task (24 hours)

The results from an independent samples t-test showed a significant effect of participant group on the semi-naturalistic PM task performance, t (49) = 2.20, p = .033, η_p^2 = .090. The inspection of means indicated that individuals with dyslexia were more likely to forget to perform the PM activity 24 hours after leaving the laboratory (*M* = 1.35, *SD* =.94) compared to non-dyslexic participants (*M* = .76, *SD* = .97).

5.1.4. Discussion

5.1.4.1. MIST

There was no significant difference in PM of individuals with dyslexia and non-dyslexic controls matched for age and IQ on the basis of MANOVA and the total MIST score t-test. Even though the MANOVA test revealed no significant difference, the follow-up univariate F-tests were explored, as the MIST is a “blunt” measure that is designed for clinical samples (e.g. Poquette et al., 2013). The results from the follow-up univariate F-tests are in line with the literature indicating an overlap between PM and dyslexia (e.g. McLoughlin et al., 1994; Smith-Spark et al., 2003; 2004; Smith-Spark & Fisk, 2007). The results of study 3 revealed significant differences between dyslexic and non-dyslexic individuals on PM tasks that involved time-based PM cues and verbal responses. Adults with dyslexia showed significant deficits in remembering to perform these PM tasks. This supported that hypothesis that individuals with dyslexia are likely to display time-based PM problems. The findings also supported the findings in Study 2 (PMQ) pointing towards time-based PM problems in dyslexia. It could be argued that individuals with dyslexia were found to have difficulties with time-based PM, as time-based PM tasks require more self-initiated processes and monitoring time. This self -initiated process can be argued to be more demanding on WM in comparison to event-based PM tasks which rely more on automatic retrieval processes (Einstein & McDaniel, 1990). This reasoning is in line with the literature arguing for WM problems in dyslexia (e.g. Smith-Spark & Fisk, 2007). Moreover, the event-based tasks cues used in MIST are directly related to the required response and therefore could naturally evoke the required response (e.g. "When I hand you an envelope, please self-address it".). This confirms that these tasks were less cognitively demanding as they allowed spontaneous retrieval to occur due to ecologically relevant event-based PM cues which involved less self-initiated processes.

The results from the analysis of memory errors indicated that individuals with dyslexia committed "loss of time" errors more times compared to controls (results approaching significance). This finding can be linked to the finding showing a time-based PM problem in individuals with dyslexia as self-initiation of time monitoring is required to gauge the required time for correct time-based PM task performance. The "loss of time" errors have been linked to difficulties with timing (Raskin, Woods, Poquette, McTaggart, Sethna, Williams & Tröster, 2011). Thus, an alternative explanation of the results which suggest a time-based PM deficit in dyslexia could be related to a problem with time estimation. This possible explanation is supported by Nicolson et al. (1995) who argue that cerebellar deficits may account for poor performance of individuals with dyslexia in time perception tasks. Since one may rely on the "internal clock" to estimate time in order to initiate checking of the time (look at the clock – prompt of PM activity), in order to be able to perform the time-based PM tasks at the appropriate times. Thus, poor time estimation could lead individuals with dyslexia to perform the correct tasks, but at an incorrect time (later than one minute from the required time) or simply to fail to perform these time-based PM tasks.

The follow-up univariate F-tests revealed a group difference with regards to PM tasks which required production of verbal responses. In these PM tasks individuals with dyslexia were significantly worse compared to controls. This result could be claimed to be consistent with the phonological difficulties found in dyslexia. For instance the phonological deficit hypothesis (Frith, 1985; Snowling, 1995) argues for a phonological processing deficit as well as encoding of verbal information difficulties in dyslexia. Similarly the double deficit theory of dyslexia (Wolf & Bowers, 1999) states that individuals with dyslexia have a slow naming speed. Also dyslexic individuals have been found to have problems with verbal fluency functions facilitating retrieval of information from memory (Felton & Wood, 1989; Griffiths, 1991; Kinsbourne, Rufo, Gamzu, Palmer & Berliner, 1991). Thus, the significant group difference acquired from the PM items of MIST in which participants were required to produce verbal responses is in line with the above studies.

The results from the mixed measures ANOVA conducted for initial investigation of the effect of memory load on the two participant groups, revealed that individuals with dyslexia were less able to remember prospectively compared to controls, regardless of the memory load condition. This finding supports the hypothesis that individuals with dyslexia have problems with PM and is in line with the self-reported PM deficits in dyslexia found in Study 1. This result also supports previous literature discussed in Chapter 3, which pointed towards PM difficulties in dyslexia (e.g. Smith-Spark et al., 2004). The main effect of PM load condition supported Basso et al. (2010) who found that PM load has a negative effect on PM performance. Nevertheless, there was no interaction between participant group and PM load condition and this was not in line with the literature regarding WM problems in dyslexia (e.g. Smith-Spark & Fisk, 2007) which was used to argue that individuals with dyslexia would have PM problems in high PM load condition. This finding was also not in line with the reasoning that insufficient WM resources prevent individuals with dyslexia from consciously compensating for their PM deficit, as argued by Nicolson and Fawcett (1990) DAD/CC hypothesis. Nicolson and Fawcett found that individuals with dyslexia were impaired at more difficult tasks compared to easier tasks and thus, the lack of interaction between the PM load and participant group is not in line with these results. PM tasks requiring a greater number of PM actions to be held in memory during the retention interval did not result in greater PM decline in individuals with dyslexia compared to controls (and relative to items involving low PM load). Nevertheless, the CC hypothesis was established on the basis of a study employing children with dyslexia whereas, in the current investigation an adult sample was used. Therefore, it is possible that these adults with dyslexia are more able to consciously compensate compared to children and thus, the PM load manipulation was not cognitively demanding enough. Furthermore, as the high PM load conditions included a mixture of event-based and time-based PM tasks, which varied in task difficulty; it is difficult to make this assumption.

5.1.4.2. Naturalistic time-based delayed task

The results showed that individuals with dyslexia were significantly less able to remember prospectively on a naturalistic time-based task, involving a 24 hour time interval between intention formation and intention execution phases. These results are consistent with the argument that memory decay processes which also apply to PM (Tobias, 2009), are more prevalent in PM tasks involving longer time intervals. This in turn could result in worse PM performance, as longer time intervals may provide more opportunities to forget to perform the

PM activity or one may be more likely to forget to monitor the time when there are longer time intervals. Nevertheless, this by itself does not explain why dyslexic individuals performed worse on this task compared to controls. It could be reasoned that distractible attention (Nicolson & Fawcett, 1990) or difficulties with inhibition of distracters (Palladino et al., 2001) played a part in the PM deficit found in dyslexia in this experiment. Namely, one can suggest that in tasks involving longer time intervals it is possible that distractibility may have a negative effect on maintaining the PM intention in memory, with the dyslexic group being more likely to forget.

There are several other theoretical possibilities that could account for these results. As this task took place in naturalistic everyday settings, it is more likely that there were many more distractions in the environment compared to a laboratory controlled setting. Therefore, one could be distracted from the PM intention and thus stop monitoring the time, leading to failure of PM. Another issue is that due to increased involvement in everyday life activities (compared to a laboratory setting) and difficulty with automatisation of some of the real life tasks, this could have resulted in a lack of available cognitive resources (e.g. WM capacity). Additionally, inhibition and task switching difficulties in dyslexia (e.g. Hari & Renvall, 2001) could be relevant in explaining the PM deficit found on the basis of this naturalistic task. That is to say, participants with dyslexia could have difficulties with inhibiting their current ongoing tasks in order to switch between the ongoing tasks and time monitoring activity/performance on the PM task.

On the other hand one may argue that dyslexic individuals have difficulties with spontaneous retrieval processes. Namely, tasks involving long time intervals are more likely to rely on spontaneous retrieval processes (McDaniel & Einstein, 2007). Since the PM task involving long time intervals may be too taxing for attentional resources to constantly monitor the environment for the appropriate time to perform the task (hold the PM intention in conscious awareness) and perform other daily tasks. Thus, individuals with dyslexia whose spontaneous retrieval processes fail would also fail to retrieve the PM intention at the appropriate time. The explanations of the naturalistic results provided briefly within this section will be expanded upon in the following chapters when considering other naturalistic and semi-naturalistic tasks.

5.1.5. Summary

The results from the MIST indicated that individuals with dyslexia may have problems with PM even though the multivariate analysis of variance was not significant. The lack of statistically significant effects may be because the MIST has been designed for use with clinical samples and thus, is not sensitive enough for more subtle difficulties with PM. Nevertheless, the two-way ANOVA results conducted on participant group and cognitive load indicated that individuals with dyslexia performed significantly worse on PM task regardless of PM task load. These results are in line with the data from questionnaires used in Studies 1 and 2, which showed that individuals with dyslexia perceive themselves as having PM problems. The MIST also indicated that there may be a problem with time-based PM in adults with developmental dyslexia. Individuals with dyslexia were found to have significantly worse performance compared to controls on the time-based PM task involving a 24 hour time interval between intention formation and execution.

The next stage of this thesis which developed organically, was to investigate both event- and time-based PM under laboratory controlled conditions in order to have a closer look at the processes that may underlie PM deficits in dyslexia. Laboratory investigation was employed with the aim of seeing if a range of different PM tasks coupled with differential processes results in identifying any PM deficits in dyslexia. The next chapter (Chapter 6) probed into an event-based PM (focal and non-focal), followed by a chapter (Chapter 7), which investigated time-based PM. These investigations were accompanied by field experiments in order to see whether there are any group differences on the different PM types under real life conditions.

Chapter 6: Event-based prospective memory

Einstein and McDaniel (1990) developed an experimental paradigm allowing the investigation of event-based PM. Einstein et al. (1995) used this basic event-based PM paradigm to investigate PM in adults. In this study participants had to answer general knowledge questions as the ongoing task (e.g. "How many hours will it take a person to walk 24 miles at the rate of three miles per hour?"). Participants were told before they started that when they saw a question with the word *president* in it they needed to press the F8 key. Then, before participants began the general knowledge questions task they were presented with a distractor task based on vocabulary. The PM cue was used six times in the ongoing activity and participants were required to respond to it by pressing the F8 key each time they saw it. PM performance was measured by the proportion of PM trials in which participants remembered to perform this PM task. Participants were generally able to remember well to perform the intended activity when encountering the PM cue (average 90% correct PM responses).

The relationship between the ongoing task and the PM cue can differ. This can depend on the characteristics of the ongoing task and PM cue (McDaniel & Einstein, 2007). Depending on the relationship between the ongoing task and PM cue, the PM cue may be characterised as being focal or non-focal (see Chapter 1). Study 4 investigated an event-based PM with focal PM cue whereas Study 5 employed a non-focal PM cue.

6.1. Experimental investigations of cue focality

As stated in Chapter 1, the focality of a PM cue depends on whether or not the processing of the PM cue is encouraged by the ongoing task, in which it is embedded (McDaniel & Einstein, 2007). In a PM task with a focal PM target the ongoing task encourages the processing of the PM cue. In contrast, PM tasks with a non-focal PM cue involve an ongoing task which does not encourage the processing of the PM cue. For example, a focal cue occurs in everyday life situations when one receives and reads an email from a friend, to whom one previously intended to forward an email with some information. This acts as a prompt to forward the email. An everyday example of a non-focal PM cue can be demonstrated in a situation where one intended to renew a monthly ticket when next passing a ticket office. The ticket office in this situation acts as an event-based cue. To make the cue non-focal it would have to be located some distance from the platform. Thus, when walking in a stream of pedestrians and attending closely to the task of passing through the automated gate to enter the platform, the ticket office would act as a non-focal cue. Under these circumstances the processing of the non-focal cue would not be encouraged by the activity engaged in (entering the platform). In this situation, if one was going to the ticket office to find out about the time of the next train, this ongoing activity would encourage the processing of the PM cue (the ticket office) which could act as a reminder about renewal of the monthly ticket. This would then be a focal PM cue.

There have been a number of experimental studies which have used focal and non-focal PM cues (e.g. Einstein et al., 2005; see Chapter 1). Rendell, McDaniel, Forbes and Einstein (2007) showed that the age related deficit of PM was significantly smaller in the focal condition compared to the non-focal condition. In other words, older adults' PM was significantly better in the focal condition compared to the non-focal. Interestingly, younger adults performed similarly well in the focal condition compared to the non-focal condition. There was no significant effect on the ongoing task caused by any type of PM task. This study demonstrated a reduction of age related differences when a focal PM cue is used relative to a non-focal PM cue and this also was not attributable to sacrificing the ongoing task performance. In addition, a second experiment manipulated the difficulty of the ongoing task and the results from this investigation indicated that when the ongoing task was made less challenging the age related difference found on the non-focal PM task were eliminated.

Other studies have also shown considerable age related deficits in PM tasks employing non-focal PM cues (e.g. Maylor 1993, 1996; Park, Hertzog, Kidder, Morrell & Mayhorn 1997) and no such deficits in PM tasks employing focal cues (e.g. Einstein & McDaniel, 1990; Einstein et al., 1995). McDaniel, Einstein and Rendell (2008) argued that these results show that PM retrieval based on focal PM cues can be automatic. This interpretation is in line with the multiprocess theory of PM. According to the multiprocess theory a focal PM cue is more likely to lead to automatic spontaneous retrieval processes and a non-focal PM cue is more likely to involve monitoring processes which employ strategic attentional resources needed for monitoring for the cue (see Einstein & McDaniel, 2005; Einstein et al., 2005; McDaniel & Einstein, 2000; 2007, for empirical support). This is in line with the results from PM tasks employing focal and non-focal PM cues in older adults. Namely, older adults showed no problems in the focal PM cue conditions as these rely on spontaneous retrieval processes which are preserved in older adults (e.g. Craik, 1986). McDaniel, Einstein and Rendell (2008) argued that the age related deficit shown in PM tasks with non-focal PM cues occurs because non-focal tasks rely on monitoring processes. These monitoring processes draw on attentional resources which are claimed to decline with age (e.g. Craik & Byrd, 1982). McDaniel and Einstein (2000) claimed that the non-focal condition, which results in a more robust deficit in PM performance, is based on resource challenges in older adults.

This claim can be the foundation for the experimental work included in this chapter (Studies 4 and 5). Namely, that the attention related deficits (visual-spatial attention, auditory attention; Varvara et al., 2014) found in individuals with developmental dyslexia (described in Chapter 2) may result in more robust PM deficits in non-focal PM tasks. Since the age related deficits of PM were more robust in the non-focal condition, due to a decline in attentional resources, it can be argued that individuals with dyslexia will also display more profound problems in non-focal PM tasks, as attentional resources have been found to be deficient in individuals with dyslexia.

Nevertheless, Schnitzspahn et al. (2013) found that inhibition and shifting was a significant predictor of event-based PM performance. They argued that the influence of shifting on PM supports the PAM theory (Smith 2003), in that shifting between the processes needed for the performance of an ongoing task and processes required for monitoring the environment are needed for successful PM performance. This point of view opposes the spontaneous retrieval theory of PM (e.g. Einstein & McDaniel, 1996) which stated that event-based PM tasks can rely on spontaneous retrieval processes, as they are argued to not require active monitoring processes and are automatic. This could indicate that regardless of whether the task employs focal or non-focal PM, individuals with dyslexia will have difficulties on these tasks, as individuals with dyslexia have been reported to have problems with inhibition and shifting (e.g. Varvara et al., 2014).

It was thus hypothesised that individuals with dyslexia would show poorer event-based PM performance compared to controls. It was also suggested that this deficit may be even more robust in the PM task with a non-focal PM cue compared to the task with a focal PM cue. The non-focal condition does not encourage the processing of the target PM cue and thus, is more cognitively demanding. The hypothesised PM deficits in individuals with dyslexia can be based on the claims that SAS, WM and higher-order cognitive processes are deficient in dyslexia (e.g. Smith-Spark & Fisk, 2007; Varvara et al., 2014), since the SAS, WM and higher-order processes are required to perform PM tasks (see Chapter 1). Moreover, WM abilities have been found to greatly influence PM performance (Smith et al., 2011). Also, allocation of attention is necessary for switching between the ongoing and PM task. These processes have been found to be deficient in dyslexia and thus are likely to result in PM deficits. This evidence (described in more detail in Chapter 1), as well as the results from Studies 1 and 2 provide the foundation for the hypothesised PM deficits in dyslexia. In addition, it can be argued that group differences may also express themselves in terms of cost and/or accuracy to the ongoing trials. Namely, differences in RTs and accuracy levels between Blocks 1 (ongoing task only) and 2 (ongoing plus PM) may be greater in participants with dyslexia compared to controls.

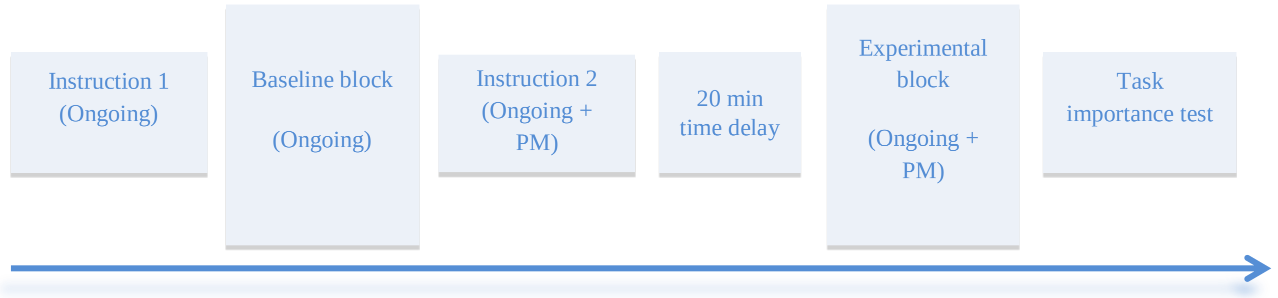
According to the multiprocess theory of PM (McDaniel & Einstein, 2000) no significant cost to the ongoing task should be found in the focal condition whereas, on the non-focal condition there should be a significant cost effect. Studies such as Einsterin et al. (2005) and Sculllin et al. (2010) support this claim (see section 1.4.4.). Thus, it is possible that in the focal condition of the current investigation, there will be no significant differences in RTs to ongoing trials from the baseline (Block 1) and PM condition (Block 2). Contrary to the multiprocess view, Smith (2003), in her PAM theory, argued that monitoring is always required in event-based PM tasks and this will result in a cost to the ongoing task. She found that cost was visible in slower RTs to ongoing trials associated with having to perform the PM activity, when compared to baseline condition which only involved ongoing task (see Chapter 1). Thus, on the basis of PAM theory, it could be hypothesised that significant cost to the ongoing task will be visible in both focal and non-focal PM tasks.

6.1.1. Study 4: Focal prospective memory target

6.1.1.1. Introduction

This study employed an experimental task to investigate event-based PM, using a focal PM cue. Participants were asked to first perform a baseline block (Block 1), which required them to perform an ongoing task only. In the ongoing task participants were shown six drawings and their task was to judge whether the majority of these pictures represented living or non-living objects. After the completion of the baseline block participants were given the instructions regarding the PM task which was embedded in the experimental block (Block 2). In between Blocks 1 and 2 there was a filler task, which lasted for 20 minutes. This provided a 20 minute time delay between intention formation and execution. Whilst experimental block (Block 2) consisted of the same ongoing task, it also incorporated an additional PM task which required participants to respond differently every time they saw a PM cue (picture of an eye or glasses). Figure 1 represents the order of instructions and blocks used in the focal and non-focal PM experiments.

Figure 1: A diagram representing the order of instructions and blocks in event-based PM experiments.



The ongoing task in this PM design encouraged processing of the features of the focal PM cue. Since the key feature of the ongoing task involved the recognition of drawings based on semantic features, the PM cues were also recognisable on the basis of semantic features. Both the ongoing task and the PM task involved judging whether or not items belonged to different semantic categories. The ongoing task required judgements whether there were more pictures representing living vs. non-living objects. The PM task required responses to items related to seeing/vision. Thus both the ongoing and PM task involved the same type of processing (i.e. semantic). This task fulfilled the requirement of a focal task as there was an overlap between the information related to the ongoing task and the features of encoded PM cue (Gordon et al., 2011). In addition, the PM cues themselves were shown to participants during the instructions phase (20 minutes before the PM task was performed). It can thus be assumed that this task was even more likely to rely on spontaneous processes of retrieval. Since showing the exact PM cues to participants is more likely to result in spontaneous retrieval processes, as PM cues previously encountered by participants could be argued to provide stronger triggering of the intended action compared to PM cues which are only described to participants, and where no actual PM cues are shown.

On the basis of the results from Studies 1 and 2 as well as the literature suggesting dyslexia difficulties relevant to PM functioning (e.g. SAS/WM, Smith-Spark & Fisk, 2007; see Chapter 3), it was hypothesised that individuals with dyslexia would display significantly lower accuracy on PM trials compared to age- and IQ-matched control participants without dyslexia. In addition, there may be a visible cost on the ongoing task performance, due to having to perform a PM task. This cost could be especially visible in individuals with dyslexia. This study also employed eye-tracker technology. The primary reason for employing eye-tracking was to eliminate the possibility that participants failed to respond to the event-based PM cue because they did not notice it. If it was the case that participants did not notice the PM cue, this alone could create differences in PM performance. Thus, it would be difficult to investigate whether there are differences in PM in the two participant samples as an alternative explanation could be provided. Namely, it could be argued that it is not a PM problem per se but rather a problem related to noticing processes. The secondary aim of using the eye-tracker was to provide more insight into monitoring processes in the two participant groups.

6.1.1.2. Method

6.1.1.2.1. Participants

Fifty university students were tested, of whom 26 had dyslexia and 24 did not. All of the participants were native English speakers and between 18 and 35 years old. The descriptive statistics (mean, SD and range for age and gender split) are included in Table 10.

Consistent with the studies reported earlier in this thesis participants from the two participant groups (dyslexics and controls) were matched for age and IQ (see Study 1). An unrelated t-tests were used in order to check if the two participant groups were matched for IQ and to differentiate the two participant groups on the literacy measures (see Table 10).

Table 10: Descriptive statistics for gender and age and t-tests performed on literacy screening measures and short-form IQ.

	Gender		*Age (years)*		*Measure*						
					WORD Spelling Age	WORD Spelling Raw Score		DAST NWR Score		WAIS-IV Short-form IQ	
Group	Male	Female	Mean	SD	N<17 years	Mean	SD	Mean	SD	Mean	SD
Controls (N = 24)	5	19	23.42	4.82	0	44.83	1.81	92.67	3.17	107.35	9.74
Dyslexics (N = 26)	5	21	23.69	3.86	17	40.38	3.83	77.65	11.75	107.29	7.90

Independent samples t-test								
WORD Spelling Raw Score			DAST NWR Score			WAIS-IV Short-form IQ		
t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
5.32	36.27	< .001	6.27	28.91	< .001	.059	48	.953

6.1.1.2.2. Materials

The experiment was designed using the Experiment Builder software for Windows (EyeLink II/CL v.4.10; SR Research). Participants sat 57cm away from a 19" computer screen (Dell 190SFP) with their head stabilised by a chin-rest. The eye-tracker (EyeLink 1000 Desktop Mount) was connected to a desktop PC and employed 9-point calibration and validation with less than 1 degree angular error for each point. This is a standard default procedure and has been used in previous studies (e.g. Abegg, Manoach & Barton, 2011). Participants responded to the task using the Microsoft Sidewinder Plug & Play USB Gamepad (X04-97602).

A total of 69 pictures were selected from the Snodgrass and Vanderwart (1980) picture set. These pictures were black and white line drawings representing living/natural and non-living/manmade objects and were 256 x 256 pixels in size. Out of these 69 pictures, 17 pictures were used as practice trials. The remaining 52 pictures were used in the experimental blocks (26 in each block). In each of the blocks there were 13 pictures representing the living/natural category (e.g. a picture of a hand or an apple) and 13 pictures representing the non-living/man-made category (a picture of an iron or fork). Different pictures were used for practice trials block one and two in order to avoid any possible interference effects between them. The pictures were selected on the basis of non-significant differences between the living and the non-living pictures in mean ratings of image agreement, picture familiarity and complexity provided by Snodgrass and Vanderwart (1980). In addition, the two stimuli groups were matched for the actual area of the objects in the 256 x 256 image files and the number of black pixels used in each drawing. This provided additional control in order to avoid any interference that could be caused by the characteristics of the stimuli e.g. size of the objects or saturation of pictures (due to having more black pixels). It is possible that these characteristics of stimuli could provide cues with regards to correct responses as some objects could be easier to identify. Stimuli were matched across the two blocks. In addition, the living and non-living types of drawings were also matched across the two blocks. No significant differences between those clusters of stimuli were present. The lists of stimuli can be seen in Appendix 1. The results of the ANOVA tests carried out on the stimuli in order to match them are presented in Appendix 2.

6.1.1.2.3. Design

Participants who scored less than 75% in Block 1 were removed from the analysis. This was to avoid the inclusion of data where a participant did not engage well with the task or potentially did not understand the instructions.

The design of this experiment consisted of two blocks, each made up of 80 trials. The first block was preceded by 12 practice trials. Block 1 (the baseline block) consisted only of ongoing trials where participants had to decide whether there were more living or non–living drawings. Block 2, in addition to the ongoing trials also had 8 PM trials where participants were expected to break out from the ongoing activity to perform a PM action i.e. press the "A" button on the key pad to indicate the presence of a picture that belonged to the seeing/vision semantic category (a picture of an eye or spectacles). The ratio of PM trials to the ongoing trials was ten per cent i.e. there were eight PM trials and seventy-two ongoing trials. The ratio is consistent with West, Carlson and Cohen's (2007) study, which also used an eye-tracker to investigate PM.

The response buttons (left and right) were counterbalanced. Fifty per cent of participants had to respond with the left shoulder button of the key pad when the majority of the six pictures belonged to the living category and with the right shoulder button when the majority of the six pictures belonged to the non-living category. The remaining fifty per cent of participants had to respond in the opposite manner (right for living and left for non-living). This ratio applied to the dyslexic and non-dyslexic groups separately. This counterbalancing of response buttons was performed in order to exclude any possible advantage in reaction time (RT) of one hand over the other over the experiment as a whole.

There was a fixed sequence in which pictures were shown to participants in the two blocks. PM cues appeared in Block 2 semi-randomly between every 8^{th} and 12^{th} trial. For instance, if the PM cue first appeared on the 9^{th} trial, it would then appear on the 21^{st} trial thereafter and then on the 30^{th} trial.

The pictures appeared on a black computer screen in two parallel horizontal rows (three pictures in each row) with 0.5cm space between each other. The order of the pictures on the screen was randomly assigned based on a random number allocation rule in both of the blocks as follows. Each trial consisted of either 5 living pictures and 1 non-living or 4 living and 2 non-living and the opposite ways around i.e. 5-1, 1-5, 4-2 and 2-4. Equal numbers of the different ratios of stimuli types were applied in each block. The order of presentation of the different split types was randomised. In addition, the PM cues were placed in random positions of a 3 x 2 grid made by the pictures so that they did not always appear in the same position as this would make the task predictable. Furthermore, there were equal numbers of the four different types of splits (5-1, 1-5, 4-2 and 2-4) that contained PM cues in Block 2. The order of appearance of these trials consisting of different splits was also randomised.

There was no time limit for providing a response to each trial. After each response was made, a fixation point appeared on the screen. A stable fixation within one degree from this point (as measured by the eye-tracker software) was required in order for the experimenter to be able to move on to the next trial by pressing a spacebar on the control computer. The time gap between the end of the baseline block and the start of the experimental block was approximately 20 minutes with no greater differences than +/- 1 minute.

6.1.1.2.3.1. Data analysis

Please note that a data trimming procedure was followed in order to investigate whether any differences would emerge. There were no major differences in the results after the data trimming process took place and hence these results together with the explanation of data trimming procedure are available in Appendices 3 (focal) and 4 (non-focal). Non-trimmed data are therefore presented in the analyses that follow.

6.1.1.2.3.1.1. Prospective memory trials

The independent samples t-tests were used to compare the means of dyslexics and controls on accuracy and RT data acquired from the PM trials.

6.1.1.2.3.1.2. Ongoing trials

A 2 x 2 mixed measures ANOVA was conducted in order to investigate differences in accuracy and RT between dyslexics and controls on the ongoing trials from Block 1 and Block 2. In addition, it was used to investigate whether there was any cost on the ongoing task performance associated with having to perform PM tasks in Block 2 (compared to Block 1 where no PM trials were present). This test employed participant group (dyslexics and vs. controls) as the between-subject factor and the type of block (Block 1 vs. Block 2) as the within-subjects factor. This is a standard method used to investigate PM cost to the performance on the ongoing trials e.g. Breneiser (2008, 2009), Einstein et al. (2005).

6.1.1.2.3.1.3. Task importance

A chi-square test was used to ensure that neither of the participant groups was more likely to place greater importance on the ongoing or PM component of Block 2.

6.1.1.2.3.1.4. Eye-tracker data

The data gathered through the use of eye-tracker was analysed using a number of statistical tests. Two measurements were taken into consideration for this analysis. The first one being the number of fixations (which comprised of the total number of eye fixations) either on ongoing task stimuli or on PM stimuli. This was determined on the basis of interest areas set to the exact size of the each picture stimuli (256 x 256 pixels in size). The total number included consecutive fixations within an interest area and refixations on the interest area (fixations initiated from outside the region). The second measure was the mean dwell time (ms) for all individual fixations within a particular area.

6.1.1.2.3.1.4.1. Prospective memory trials

In order to check if PM failures were due to failures to notice PM cues, the data were coded using a binary coding system. This involved assigning either a score of one or zero to each of the eight PM cues for each participant separately. A score of zero was given to PM cues when no eye fixations were recorded within the interest area of that particular PM cue. A score of one was assigned to PM cues where at least one eye fixation was recorded. This allowed calculating the total number of PM cues on which each participant had no eye fixations.

Individual PM accuracy scores (%) were recalculated after removing the PM trials where no PM responses were made and participants did not fixate their eyes on PM cues of these trials. These recalculated PM accuracy scores were reanalysed using independent t-test comparison between dyslexics and controls. This was performed in order to check if a failure to notice the PM cue (as measured by lack of fixations on PM cues) affected the accuracy of PM responses in both participant groups.

An independent samples t-test was used in order to compare controls and dyslexics with regards to the percentage of the total numbers of PM trials to which participants responded incorrectly as well as correctly without fixating on the PM cues. This analysis was performed in order to provide an insight into visual fixation patterns and monitoring processes.

An independent samples t-test was also used to compare dyslexics and controls in relation to the total numbers of eye fixations and mean dwell times (ms) on the PM cues.

6.1.1.2.3.1.4.2. Ongoing task trials

Similarly to the analysis performed on the accuracy and RT data acquired from ongoing trials, a 2 x 2 mixed measures ANOVA was used in order to investigate group differences in the total numbers of fixations and mean dwell times (ms) on the ongoing stimuli in Blocks 1 and 2. This test employed participant group (dyslexics and vs. controls) as the between-subject factor and the type of block (Block 1 vs. Block 2) as the within-subjects factor.

6.1.1.2.4. Procedure

Informed consent was acquired from all participants prior to testing. Background information about participants age, gender and dyslexia status, were collected before administration of the short-form IQ and literacy measures. After completion of these measures participants were asked to sit in front of the eye-tracker with their head mounted on a chin-rest. The calibration using 9 points was conducted and validated for each participant before Block 1 and Block 2. During this process participants were asked to follow a dot on the screen which moved into different positions.

After calibration and validation participants saw instructions displayed on the screen. These instructions were recorded by a native English speaker and played out loud to every participant. The first instruction informed participants that they would see a series of displays on which six drawings would be presented and that all of those drawings could be classed as either living (natural) or non-living (man-made). Participants were then told that they would need to make a decision as to whether the majority of the six pictures presented on the screen belonged to the living or non-living category. If the majority of the six pictures shown on the screen belonged to the living category, participants had to press the left shoulder button. When the majority of the six pictures belonged to the non-living category participants had to press the right shoulder button. The response buttons (left and right) were counterbalanced for dyslexic and non-dyslexic participants i.e. the right shoulder button for the living category and the left for non-living. Participants were asked to make their decisions as quickly and as accurately as possible. There were twelve practice trials with feedback after each trial for the participants to learn how to respond to the task. The experimenter was present during the practice trials to further clarify the instructions if they were not understood and to answer any questions. After the practice trials, participants were shown an instruction screen showing all of the 26 pictures that were used in Block 1 grouped into two categories (living and non-living). This was performed in order to clarify which of the objects belonged to the living category and which to the non-living category and to remove any possible ambiguity. After this instruction participants engaged with Block 1, which consisted of eighty trials where feedback was not provided. At the end of Block 1, participants were instructed that in twenty minutes time they would need to do a similar task but with one additional task to be performed. The additional task involved pressing the "A" button on the key pad every time a picture related to the semantic category of vision/seeing appeared on the screen. Participants were shown the two target drawings associated with vision/seeing at that point, one of an eye and the other of a pair of spectacles. It was explained that the "A" button responses are required instead of the living versus non-living responses in trials that contained those pictures. No further reminders of the PM task were presented thereafter.

Participants were then taken away from the eye-tracker computer and seated at another desk in a different part of the room where they engaged with distractor tasks (WM span tasks). After twenty minutes the participants were asked to again sit in front of the eye-tracker computer, where they continued with the focal event-based PM experiment. Participants were shown an instruction screen that presented all of the living and non-living stimuli pictures used in Block 2 (excluding the PM targets) before the task began. At the end of Block 2 which also consisted of eighty trials with no feedback, participants were asked whether they remembered the instruction to respond differently to the picture of an eye or glasses. Participants who stated that they did remember this instruction were asked whether they had placed more importance on responding correctly to the ongoing task (living versus non-living) or the PM task (vision/seeing) task.

6.1.2.3. Results

6.1.2.3.1. Excluded participants

Six members of the control group were removed from the data set and replaced due to them showing literacy characteristics that were not within the normal adult range. Also, seven participants (five controls and three dyslexics) whose IQ was below 90 were removed from the analysis. There were two participants with dyslexia and one participant without dyslexia who did not respond to the PM cues at all, therefore the means of RT data for PM trials were calculated without these participants. One control participant did not reach the 75% accuracy benchmark in Block 1 and therefore was removed from the analysis. The number of participants reported in the Participants section is the number who took part after removing those who did not meet the above criteria.

6.1.2.3.2. Prospective memory trials

6.1.2.3.2.1. Accuracy

An independent samples t-test performed on the PM accuracy data (%) showed that there was no significant difference between participants with dyslexia (*M* = 81.25, *SD* = 30.26) and without dyslexia (*M* = 83.33, *SD* = 27.25), t (48) = .255, p =.800.

6.1.2.3.2.1.1. Corrected accuracy

The reanalysis of PM accuracy (%) involved removing PM trials in which participants did not respond to PM cues and did not fixate their eyes on them. The participant groups comparison performed using independent samples t-test showed no significant differences between dyslexics (*M* = 83.03, *SD* = 30.59) and controls (*M* = 86.09, *SD* = 27.12), t (48) = .372, p = .712.

6.1.2.3.2.2. Reaction time

The RT (ms) data from correct PM trials analysed using unrelated t-test showed that participants with dyslexia were significantly slower (*M* = 1652.84, *SD* = 679.32) compared to controls (*M* = 1260.89, *SD* = 361.94) when responding to the PM trials, t (35.40) = 2.48, p =.018.

6.1.2.3.3. Ongoing trials accuracy and reaction time

The results in Table 11 show descriptive statistics for accuracy and RT data for correct ongoing responses in each block.

Table 11: Descriptive statistics for accuracy and RT data of ongoing trials in Blocks 1 and 2 of focal PM paradigm.

	Accuracy (%)				RT (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	95.05	5.62	96.73	3.18	1804.80	435.23	2552.25	972.64
Ongoing (Block 2)	95.54	8.71	97.70	2.19	1885.92	353.21	2696.92	951.96

Two mixed measures ANOVAs were performed in order to compare the performance of individuals with and without dyslexia on the ongoing trials in Blocks 1 and 2 (excluding PM trials). This allowed also to investigate the cost of having to perform the PM task on the ongoing trials performance of Block 2.

The accuracy (%) analysis showed non-significant effects of both participant group, F (1, 48) = 2.13, p = .151, η_p^2 = .042. and block type, F (1, 48) = .835, p = .365, η_p^2 = .017. There was also no significant interaction between the two factors, F (1, 48) = .090, p = .766, η_p^2 = .002.

The results from the RT data showed a significant main effect of group, F (1, 48) = 14.661, p < .001, η_p^2 = .234. Inspection of the means indicated that dyslexics took generally significantly longer to respond to the ongoing trials. The effect of block type was close to significance, F (1, 48) = 3.91, p = .054, η_p^2 = .075. Inspection of the means suggested that overall participants took longer to respond to the ongoing trials of Block 2 compared to Block 1. There was no significant interaction between participant group and type of block in terms of RT, F (1, 48) = .315, p = .577, η_p^2 = .007.

6.1.2.3.4. Task importance

At the end of the experiment all participants were asked to indicate whether they placed more importance on the ongoing or the PM components of Block 2. A Chi-square test of the significance of the difference in proportions was used to analyse the data. There was no association between participant group and the component on which more importance was placed, $X^2 = .000$, df = 1, $p = 1.00$. The frequency counts for both participant groups are displayed in Table 12.

Table 12: Frequency counts representing importance placed on the different tasks by dyslexics and controls in the focal task.

	Participant group	
Type of task	Controls	Dyslexics
PM	12	13
Ongoing	12	13

6.1.2.3.5. Eye-tracker data

6.1.2.3.5.1. Noticing failure analysis

Dyslexics ($M = 2.88$, $SD = 5.37$) did not differ significantly compared to controls ($M = 3.65$, $SD = 6.88$) in terms of the percentage of total PM cues on which they did not fixate their eyes and to which they did not respond correctly, $t(48) = .438$, $p = .663$. However, controls ($M = 9.38$, $SD = 11.80$) differed compared to dyslexics ($M = 3.37$, $SD = 8.33$) in terms of the percentage of total PM cues on which they have not fixated their eyes but still responded to them correctly, $t(41.05) = 2.06$, $p = .045$. Even though this difference was not significant when a Bonferroni corrected alpha level of .025 was applied, it still indicated that there was a difference in eye fixation patterns between the two participant groups with controls fixating eyes their less on the PM cues in trials to which correct PM responses were provided compared to dyslexics who tended to fixate their eyes on these PM cues more.

6.1.2.3.5.2. Number of fixations and dwell time

6.1.2.3.5.2.1. Prospective memory stimuli

Group differences regarding the total number of fixations and mean dwell time (ms) on PM stimuli were analysed using independent samples t-test. The results showed that dyslexics (*M* =

25.69, *SD* = 9.11) fixated significantly more on PM cues compared to controls (*M* = 18.88, *SD* = 5.90), *t* (43.20) = 3.17, *p* = .003. The mean dwell time data revealed that dyslexics (*M* = 396.38, *SD* = 143.12) dwelled longer on PM cues compared to controls (*M* = 288.83, *SD* = 91.73), *t* (48) = 3.13, *p* = .003. In both cases, a Bonferroni corrected alpha level of .025 was applied.

6.1.2.3.5.2.2. Ongoing stimuli

The results in Table 13 show the descriptive statistics for number of fixations and mean dwell time data for ongoing stimuli responses in Block 1 and Block 2.

Table 13: Descriptive statistics for the number of eye fixations and dwell times for ongoing stimuli in Blocks 1 and 2.

Means	Number of fixations				Mean dwell time (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	502.75	144.37	700.46	242.30	385.13	114.46	583.85	257.19
Ongoing (Block 2)	494.13	118.62	679.50	234.93	378.34	85.12	573.23	245.30

A mixed measures ANOVA was used in order to compare the number of eye fixations made by dyslexics and controls on the ongoing stimuli in Blocks 1 and 2 (determined by interest areas related to the ongoing stimuli). The results showed a significant main effect of participant group, *F* (1, 48) = 13.05, *p* = .001, η_p^2 = .214. After the inspection of means, it could be stated that dyslexics fixated their eyes on the ongoing stimuli in Blocks 1 and 2 significantly more than controls. The effect of block type was not significant, *F* (1, 48) = .932, *p* = .339, η_p^2 = .019. There was no significant interaction between participant group and block type, *F* (1, 48) = .162, *p* = .689, η_p^2 = .003.

The results from a mixed measures ANOVA conducted on mean dwell time (ms) data revealed a significant main effect of participant group, *F* (1, 48) = 13.65, *p* < .001, η_p^2 = .221. Inspection of the means indicated that dyslexics dwelled significantly longer on the ongoing stimuli in

Blocks 1 and 2 compared to controls. The effect of block type was not significant, F (1, 48) = .401, p = .529, η_p^2 = .008. This indicated that both participant groups did not differ significantly in the length of dwell time on the ongoing stimuli in Block 1 compared to Block 2. There was no significant interaction between participant group and block type, F (1, 48) = .019, p = .890, η_p^2 < .001.

6.1.2.4. Discussion

The PM accuracy data from this experiment did not indicate that participants with dyslexia have a deficit with PM and, thus, the results did not support the hypothesis. The effect of block type found in the ongoing task RT data was approaching significance (.054). This could indicate that there was a cost related to performing the PM task which revealed itself in the RTs to the ongoing trials irrespective of participant group. As the results approached significance this does not provide robust support for the multiprocess view of PM (McDaniel & Einstein, 2000), which states that PM tasks employing focal PM cues rely on automatic spontaneous retrieval processes (see Einstein et al., 2005, for empirical support) and thus, would predict that there should be no cost related to performing PM task visible on the ongoing trials.

Individuals with dyslexia had significantly slower RTs compared to individuals without dyslexia when responding to PM cues and ongoing trials. This is in line with the double-deficit hypothesis of dyslexia (e.g. Wolf and Bowers, 1999; see Chapter 2 for more details) which states that there is a processing speed deficit in individuals with dyslexia. Also, the results revealed that individuals with dyslexia focally fixated on the stimuli significantly more compared to controls. This could mean that individuals with dyslexia tried to compensate for their attentional deficit by monitoring the screen significantly more compared to controls, and this could have resulted in there being no PM deficit found. Since larger number of eye-fixations could be indicative of a greater allocation of attentional resources by individuals with dyslexia in order to compensate for an attentional deficit. However, this is debatable, as PM tasks with focal cues strongly encourage spontaneous retrieval processes which rely on the PM cue for the retrieval of the PM intention (McDaniel & Einstein, 2007). This type of retrieval has been argued to be automatic (McDaniel, Einstein & Rendell, 2008) and thus, it is less likely for participants to rely on conscious monitoring under focal task conditions. Thus, if this is the case, why were there more eye fixations recorded in the dyslexic group? It may be possible that individuals with dyslexia relied more on monitoring processes compared to controls, who relied more on spontaneous retrieval resulting in fewer eye fixations. This could be a form of coping strategy employed by individuals with dyslexia in order to avoid PM failure. This type of strategy is in line with the proposed by Nicolson and Fawcett (1990) conscious compensation (CC) used by individuals with dyslexia.

Moreover, Marsh, Cook and Hicks (2006) suggested that each participant decides, before starting the task the level of attentional resources to allocate on the basis of the perceived difficulty of the task. Thus, it is also possible that individuals with dyslexia perceived this task as more difficult than controls. As a result, they may have decided to allocate more attentional resources, by employing monitoring processes as a coping strategy in order to perform well on this task and mask a PM deficit. Nevertheless, if participants with dyslexia relied more on monitoring processes, then one could argue that individuals with dyslexia should have a poorer performance on either the PM or ongoing task (or both tasks), as they have been reported to struggle in cognitively demanding tasks (e.g. Nicolson and Fawcett, 1990; for a discussion see Chapter 2), but no interaction effects were found. Performing an ongoing task and monitoring for PM cues could be argued to be cognitively demanding. According to Marsh, Hicks & Cook (2005) if both tasks (ongoing and PM) use the same domain (e.g. semantic as it was the case in this experiment) the cognitive resources available for this type of processing have to be shared and this will result in a poorer performance showing either on the ongoing, PM or both tasks. In addition, if one was employing monitoring processes to perform this PM task, it would add to the cognitive demand and would require additional attentional resources and WM capacity. Both of these types of capacities have been found to be deficient in dyslexia (e.g. Smith-Spark, Fisk, Fawcett & Nicolson, 2003; Smith-Spark & Fisk, 2007; Varvara et al., 2014; see Chapter 2).

Nevertheless, the results of this study did not show that there were any performance related differences between dyslexics and controls on either the PM or ongoing tasks. Thus, it is possible that individuals with dyslexia generally took significantly longer to perform the ongoing and PM tasks, in order to compensate for the capacity related deficit. It might be argued that if there was a time limit to perform the ongoing task, PM failures could become visible in individuals with dyslexia. This seems to be a more plausible explanation of the results in contrast to previously suggested problem with processing speed of the stimuli. Since individuals with dyslexia had slower processing speed, they should have similar numbers of eye fixations in comparison to control participants, but show longer dwell times. Supposing that it takes longer for participants with dyslexia to process the stimuli cognitively, they would not necessarily need to fixate their eyes significantly more times compared to controls, but could just fixate them in a specific point and dwell on it while cognitive processing takes place. However, this was not the case. Individuals with dyslexia were found to have significantly more eye fixations as well as longer mean dwell times. Thus, it is possible that participants with dyslexia generally took longer to respond to the tasks, not only due to slower processing speed but that they also tried to consciously compensate for their PM deficits (this is in line with CC hypothesis; Nicolson & Fawcett, 1990). Namely, a greater amount of monitoring was performed by dyslexic individuals to compensate for PM deficit resulting in similar to controls PM performance. Since greater monitoring of the stimuli provides greater chances of PM intention retrieval as the embedded in the ongoing task PM cue is more likely to be recognised as associated with the intended action.

6.1.2. Study 5: Non-focal prospective memory target

6.1.2.1. Introduction

Despite no deficits being found on a focal task, it was decided to explore event-based PM further using non-focal PM design in order to create conditions where it is more difficult for individuals with dyslexia to use conscious compensation (Nicolson & Fawcett, 1990). It was thought that this might reveal PM deficits in dyslexia. Therefore, a non-focal event-based PM design was used in order to see whether limiting the use of conscious compensation would result in a PM deficit being revealed. In line with the multiprocess view (McDaniel & Einstein, 2000) non-focal PM tasks are more difficult as they require more monitoring processes in comparison to focal PM tasks, which can rely on spontaneous retrieval processes (see Chapter 1). Thus, the non-focal type of event-based PM task should make the use of conscious compensation for individuals with dyslexia more difficult. The inability to consciously compensate for the cognitive deficits present in dyslexia (e.g. attention, SAS, WM or EF; Smith-Spark & Fisk, 2007; Varvara et al., 2014; see Chapters 2) might thus reveal PM deficits. In addition, if individuals with dyslexia employ conscious compensation, it is likely that this would be to a lesser extent when compared to the focal design, as cognitive resources would be more occupied by the non-focal task, than in the focal task. This is due to the non-focal task encouraging less processing of the PM cue and thus, employing more monitoring processes in order to successfully complete the task i.e. switch from the ongoing task to the PM task when encountering the PM cue. These monitoring processes have been reported to draw on cognitive resources such as resource-demanding attentional processes, which are allocated by the executive attentional systems e.g. SAS (McDaniel & Einstein, 2007). The SAS and attention (visou-spatial and auditory) processes have been found to be deficient in dyslexia (e.g. Smith-Spark & Fisk, 2007; Varvara et al., 2014). Other researchers reasoned that individuals with dyslexia may have fewer attentional resources to bring to bear (e.g. Facoetti et al., 2000; Hari & Renvall, 2001). Therefore, conscious compensation processes may be necessary for individuals with dyslexia in order to perform at similar levels to controls. This may be especially important in a non-focal PM task as greater attentional resources for monitoring are needed. If conscious compensation processes are prevented due to insufficient or deficient attentional resources, performance on the task could be impaired.

The current study therefore employed an experimental task investigating event-based PM with a non-focal PM cue. This experiment's design mirrored very closely the focal experiment but employed a non-focal PM cue instead of a focal one. Thus, the processing of the ongoing task did not trigger or encourage processing of the features relevant to the PM task. The key feature of the ongoing task involved the semantic recognition of drawings (the same task as in the focal condition - judging whether there are more pictures representing living vs. non-living objects), but the PM task was based on the perceptual characteristics of the pictures. Namely, participants had to look for the pictures which had an outer line in the shape of a circle (see Appendix 5 for the stimuli). The order of instructions and blocks was the same as in the focal experiment and is represented in Figure 1. This task fulfilled the requirement of a non-focal task as there was no overlap between the information related to the ongoing task and the features of the PM cue that had been encoded (Gordon et al., 2011). In addition, the exact PM cues were not shown to participants during the instructions phase (which occurred 20 minutes before the PM task was presented) and thus it can be assumed that this task encouraged the use of monitoring processes even more. It was hypothesised that individuals with dyslexia would display significantly lower accuracy on PM trials in this non-focal event-based PM task compared to age- and IQ-matched control participants without dyslexia. It was also hypothesised that a cost to the ongoing task performance would be visible for all participants and that this would be even greater in individuals with dyslexia compared to controls.

6.1.2.2. Method

6.1.2.2.1. Participants

The same selection criteria were used as in the focal experiment. A total of 43 university students between 18 and 35 years old took part in this non-focal design. Twenty-two of those participants were individuals with dyslexia and twenty-one without dyslexia. The two participant groups were matched for their age and IQ. Participants' literacy skills were assessed using literacy measures (for more details about the general participant matching procedure, please see Participants section of Chapter 4). The descriptive statistics and unrelated t-tests comparing the two participant groups on literacy and short-form IQ measures are displayed in Table 14.

Table 14: Descriptive statistics for gender and age and t-tests on literacy screening measures and short-form IQ for the non-focal experiment.

	Gender		*Age (years)*		*Measure*						
					WORD Spelling Age	WORD Spelling Raw Score		DAST NWR Score		WAIS-IV Short-form IQ	
Group	Male	Female	Mean	SD	N< 17 years	Mean	SD	Mean	SD	Mean	SD
Controls (N = 22)	4	18	24.86	5.34	0	45.23	1.80	93.41	2.79	109.08	8.19
Dyslexics (N = 21)	7	14	24.95	3.91	10	41.29	3.84	79.52	11.80	110.85	9.40

Independent samples t-test	WORD Spelling Raw Score			DAST NWR Score			WAIS-IV Short-form IQ		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
	4.28	28.09	< .001	5.26	22.13	< .001	.660	41	.513

6.1.2.2.2. Materials

The materials used for this experiment were the same as in the focal experiment except that different stimuli were used. The same selection criteria were used for selecting the stimuli from Snodgrass and Vanderwart (1980) pool of drawings. The only difference in the selection procedure of stimuli for the non-focal experiment was that in Block 2 there was one round object (where the outer line of the drawing was in a shape of a circle) which belonged to the living category (drawing of an orange) and one that belonged to the non-living category (drawing of a button). These two pictures can be seen in Appendix 5. The remaining 24 drawings (12 from the living category and 12 from the non-living) did not represent any round objects or did not have any outer lines of the drawings in the shape of a circle. Please see the Materials section for the focal experiment for further details about the materials used. The tests performed to match stimuli can be seen in Appendix 2.

6.1.2.2.3. Design

See section 6.1.1.2.3.

6.1.2.2.4. Procedure

Exactly the same procedure was followed as in the focal experiment except that there was a different type of PM cue. Namely, a non-focal type of PM was used and participants were told to look for a round object (a picture which had an outer line in the form of circle) and press the “B” button when they saw it. Participants were shown examples of such objects, but the actual PM cues were not shown to participants before the task.

6.1.2.3. Results

6.1.2.3.1. Excluded participants

Two members of the control group were removed from the data set and replaced due to showing literacy characteristics that were not in the adult range. Also, three participants whose IQ was below 90 were removed from the analysis. The information provided in the Participants section does not include these participants.

6.1.2.3.2. Prospective memory trials

6.1.2.3.2.1. Accuracy

The results from the unrelated t-test performed on the PM accuracy data (%) revealed that there was a non-significant difference between participants with dyslexia (*M* = 71.43, *SD* = 28.82) and without dyslexia (*M* = 77.84, *SD* = 24.68), *t* (41) = .785, *p* =.437.

6.1.2.3.2.1.1. Corrected accuracy

The reanalysis of the PM accuracy (%) in which PM trials with no responses to PM trials in which participants did not fixate their eyes PM cues showed no significant differences between dyslexics (*M* = 78.02, *SD* = 29.20) and controls (*M* = 81.82, *SD* = 25.63), *t* (41) = .454, *p* = .652.

6.1.2.3.2.2. Reaction time

The independent samples t-test performed on the RT (ms) data from correct PM responses showed that there were non-significant differences between participants with dyslexia (*M* = 1362.98, *SD* = 679.32) and participants without dyslexia (*M* = 1085.80, *SD* = 426.86), *t* (41) = 1.69, *p* =.100.

6.1.2.3.3. Ongoing trials accuracy and reaction time

The results in Table 15 show descriptive statistics for accuracy and RT data for correct ongoing responses in each block.

Table 15: Descriptive statistics for accuracy and RT data of ongoing trials in Blocks 1 and 2 of non-focal PM paradigm.

	Accuracy (%)				RT (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	96.59	3.25	96.07	4.17	1469.40	454.15	2113.64	897.80
Ongoing (Block 2)	95.77	3.85	95.50	6.50	1586.67	403.17	2323.68	937.98

A 2 x 2 mixed measures ANOVA was used to compare the accuracy (%) of individuals with and without dyslexia on the ongoing trials in Blocks 1 and 2. It showed a non-significant effect of both participant group, F (1, 41) = .129, p = .722, η_p^2 = .003. and block type, F (1, 41) = .641, p = .428, η_p^2 = .015. There was also a non-significant interaction between the two factors, F (1, 41) = .021, p = .885, η_p^2 = .001.

The same analysis conducted on the RT data showed a significant main effect of participant group, F (1, 41) = 10.70, p = .002, η_p^2 = .207. Inspection of the means indicated that participants with dyslexia were significantly slower when correctly responding to ongoing trials across Blocks 1 and 2 compared to controls. There was also a significant main effect of block type, F (1, 41) = 10.88, p = .002, η_p^2 = .210. Inspection of means indicated that overall both participant groups were significantly slower when correctly responding to the ongoing trials in Block 2 compared to Block 1. There was no significant interaction between the two factors, F (1, 41) = .874, p = .355, η_p^2 = .021.

6.1.2.3.4. Task importance

As in Study 4, a Chi-square test of the significance of the difference in proportions was used and showed that participants with or without dyslexia were not significantly more likely to place more importance on the ongoing or PM trials of Block 2, X^2 = .024, df = 1, p = .876. The frequency counts for both participant groups are displayed in Table 16.

Table 16: Frequency counts representing importance placed on the different tasks by dyslexics and controls in the non-focal design.

	Participant group	
Type of task	Controls	Dyslexics
PM	11	10
Ongoing	11	11

6.1.2.3.5. Eye-tracker data

6.1.2.3.5.1. Noticing failure analysis

Participants with dyslexia (*M* = 8.33, *SD* = 10.70) did not differ significantly compared to controls (*M* = 5.68, *SD* = 7.45) in terms of the percentage of total PM cues on which they have not fixated their eyes and to which they did not respond correctly, t (41) = .947, p = .349. There were also no significant differences between participants with dyslexia (*M* = 14.29, *SD* = 21.39) and controls (*M* = 11.93, *SD* = 15.18) in terms of the percentage of total PM cues on which they have not fixated their eyes but still responded to them correctly, t (41) = .418, p = .678.

6.1.2.3.5.2. Number of fixations and dwell time

6.1.2.3.5.2.1. Prospective memory stimuli

An unrelated t-test showed that dyslexics (*M* = 23.43, *SD* = 8.12) fixated their eyes on PM cues significantly more compared to controls (*M* = 18.23, *SD* = 6.82), t (41) = 2.28, p = .028. There were non-significant differences between individuals with dyslexia (*M* = 300.91, *SD* = 122.68) and controls (*M* = 254.88, *SD* = 96.27) in them of mean dwell time (ms) on PM cues, t (41) = 1.37, p = .177. Nevertheless, inspection of means indicated that there were some differences in mean dwell times of dyslexics and controls. Dyslexic participants dwelled more than controls and this was in line with the previous experiment (focal).

6.1.2.3.5.2.2. Ongoing stimuli

The results in Table 17 show descriptive statistics for number of fixations and mean dwell time data for ongoing stimuli responses in Block 1 and Block 2.

Table 17: Descriptive statistics for the number of eye fixations and dwell times for ongoing stimuli in Blocks 1 and 2 of the non-focal design.

Means	Number of fixations				Mean dwell time (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	395.36	138.29	609.14	238.93	297.95	94.09	472.97	235.75
Ongoing (Block 2)	402.45	137.95	625.24	250.63	300.71	84.27	499.95	240.50

A mixed measures ANOVA was used in order to compare the number of eye fixations made by dyslexics and controls on the ongoing stimuli in Blocks 1 and 2. The results showed a significant main effect of participant group, F (1, 41) = 14.03, p = .001, η_p^2 = .225. It could be noted after the inspection of means that individuals with dyslexia fixated their eyes on the ongoing stimuli in Blocks 1 and 2 significantly more compared to controls. The effect of block type was not significant, F (1, 41) = .573, p = .453, η_p^2 = .014 which showed that both participant groups did not differ significantly in the numbers of eye fixations on the ongoing stimuli in Block 1 compared to Block 2. There was no significant interaction between participant group and block type, F (1, 41) = .086, p = .770, η_p^2 = .002.

The mixed measures ANOVA conducted on mean dwell time (ms) data revealed a significant main effect of participant group, F (1, 41) = 12.48, p = .001, η_p^2 = .233. The inspection of means showed that dyslexics dwelled significantly longer on the ongoing stimuli in Blocks 1 and 2 together compared to controls. The effect of block type was not significant, F (1, 41) = 1.49, p = .229, η_p^2 = .035 which indicated that both participant groups did not differed significantly in the length of dwell time on the ongoing stimuli in Block 1 compared to Block 2. There was no significant interaction between participant group and block type, F (1, 41) = .988, p = .326, η_p^2 = .024.

6.1.2.4. Discussion

The results from this event-based PM experiment employing a non-focal PM cue did not show any difference in performance accuracy on the PM task between participants with dyslexia and age- and IQ-matched controls without dyslexia. Thus, the group hypothesis was not supported.

The RT data showed that participants with dyslexia were significantly slower at responding to the ongoing trials (in Block 1 and Block 2). This is in line with the double-deficit hypothesis of dyslexia (e.g. Wolf and Bowers, 1999; see Chapter 2) which states that there is a processing speed deficit in individuals with dyslexia. Also, all participants were significantly slower when responding to the ongoing trials of Block 2 compared to the ongoing trials of Block 1. This shows that there was a cost visible in the RT data reflecting the fact that participants have to perform the additional non-focal PM task. This is in line with the multiprocess theory of PM (McDaniel & Einstein, 2000), which states that PM tasks with non-focal PM cues are more likely to rely on monitoring processes which are not automatic and draw on attentional resources, leading to a slowing of responses on the ongoing task (see Einstein et al., 2005, for empirical support).

It was also found that participants with dyslexia had significantly more eye fixations and longer dwell times on the ongoing stimuli compared to controls. Similarly to the focal experiment, this could be interpreted as indicating that the cost related to performing the PM task was even greater in participants with dyslexia. It may be also suggested that because participants with dyslexia monitored more, this has resulted in a PM performance similar to controls, as monitoring has been claimed to improve PM performance (Smith, 2003). This argument is related to the CC hypothesis in dyslexia (Nicolson & Fawcett, 1990). Namely, it is possible that in line with the CC hypothesis, individuals with dyslexia consciously compensated in this experiment by employing more monitoring processes. This could in turn result in non-significant differences between the two groups in terms of accuracy of performance, as participants with dyslexia were able to consciously compensate for their cognitive deficits (e.g. attention/SAS/WM/EF; Hari & Renvall, 2001; Varvara et al., 2014; see Chapter 2). If individuals with dyslexia did not have enough executive resources available to perform this task, monitoring the screen more compared to controls should have resulted in worse accuracy on PM or ongoing trials because monitoring processes are capacity consuming (Einstein et al., 2005). However, no accuracy related deficit was found in individuals with dyslexia compared to controls. Thus, it is possible that the non-focal task failed to prevent conscious compensation enough to reveal a PM deficit in dyslexia. The only difference that was found was related to RTs, with dyslexic individuals having greater RTs compared to controls. Therefore, it can be argued that if there was a time limit in each of the trials, adding a time pressure to performance, or if the task was more cognitively demanding (using more resources), it is possible that individuals with dyslexia would not be able to employ conscious compensation processes to compensate for any PM deficit e.g. Nicolson and Fawcett (1994).

No direct comparison between the focal and non-focal tasks can be made, as different samples were used. It could be that the non-focal task as well as the focal task were simply not cognitively demanding enough for the PM deficit to show in individuals with dyslexia. This is in line with the general line of argument presented by Nicolson and Fawcett (1990) who stated that cognitive deficits in dyslexia are visible on more difficult tasks. It is also possible that there is no event-based PM deficit in dyslexia.

6.1.3. General discussion (cue focality)

The results did not reveal event-based PM problems in dyslexia under focal and non-focal task conditions. There were also no significant group differences in the accuracy of performance on the ongoing trials. A cost to the ongoing task performance was found in both tasks (focal and non-focal). Overall, participants were slower at responding to the ongoing trials in the PM block compared to the baseline block. It was also found that participants with dyslexia focally fixated more on all types of stimuli relative to controls.

The relationship between the ongoing task and the PM cue can differ. According to the multiprocess view (McDaniel & Einstein, 2000), the demands and the nature of the ongoing task have an effect on the degree of processing of the PM cue. Moreover, the relationship between the characteristics of the ongoing task and the PM cue are important in determining which processes will support PM. According to the multiprocess theory, a focal PM cue is more likely to lead to automatic spontaneous retrieval processes and a non-focal PM cue is more likely to involve monitoring processes which employ the strategic attentional resources needed for monitoring for the cue (see Einstein et al., 2005, for empirical support). Studies (e.g. Marsh et al., 2003) have shown that PM tasks with focal PM cues result in a better PM performance than tasks with non-focal PM cues. On the contrary, a study conducted by Rendell et al. (2007) showed that younger adults performed similarly well in their focal condition compared to their non-focal condition. The samples of controls used in the current experiments were young adults and the results from the focal and non-focal experiments (described in this chapter) tend to support the findings of Rendell et al. (2007). There were only small differences in the PM accuracy figures between the focal and non-focal conditions of individuals without dyslexia (83% in the focal PM task versus 78% in the non-focal PM task; see Appendix 6 for juxtaposition of tables displaying means from focal and non-focal experiments). Nevertheless, the differences in the PM accuracy figures could be caused by other factors such as the choice of stimuli used within these experiments. Although the stimuli were matched on the basis of image agreement, picture familiarity, complexity, area of the objects in the image files and the number of black pixels used in each drawing across the blocks and across the types of different stimuli, some drawings used may be deemed as more attention grabbing than others. In particular, the drawing of an eye used as a PM cue in the focal experiment could be argued to be more attention grabbing than the drawings employed in the non-focal experiment which used a drawing of a button and orange as the PM cue. This could potentially create confounding problems resulting in the focal task being generally easier as it could have relied more on spontaneous retrieval due to a highly salient PM cue. Whereas the PM cue in the non-focal experiment may have been less salient. According to multiprocess theory of PM (McDaniel & Einstein, 2000) salient PM cues are more likely to result in automatic retrieval of the PM intention compared to less salient PM cues which were argued to rely more on monitoring processes. Thus, the drawing of glasses used in the focal design as the second PM cue could be argued to be less salient and thus could result in monitoring processes being employed for the completion of this task. Smith et al. (2007) argued that PM tasks with salient PM cues should not result in cost to the ongoing task performance. Thus, if one would deem the drawing of the glasses used as a PM cue in the focal design as not salient, this could result in a cost to the ongoing task, as monitoring processes would have to be employed for successful PM performance. This may explain the cost to the ongoing task found in the focal design.

Rendell et al. (2007) revealed an age related PM deficit which was significantly smaller in the focal condition compared to the non-focal condition. This finding showed that the PM of older adults was significantly better in the focal condition compared to the non-focal condition. Also, this reduction of age related differences in PM tasks employing a focal PM cue relative to a non-focal PM cue was not attributable to a sacrifice of performance on the ongoing task. The reduction of PM performance related to aging has been claimed to occur due to a decline of attentional resources in older adults (McDaniel et al., 2008). In line with this thinking it was hypothesised that individuals with dyslexia should show a PM deficit compared to controls and that this deficit should be more profound in the non-focal condition compared to the focal condition. Even though the current investigation employed young adults and not older adults, individuals with dyslexia have also been found to have attention related deficits (e.g. Hari & Renvall, 2001; see Chapter 2). Such task-related difference was reflected in the results of the current investigation. There were no differences found in the accuracy of PM between individuals with and without dyslexia in the non-focal experiment. Nevertheless, the comparison of PM accuracy between the focal and non-focal designs revealed that the dyslexic individuals showed a larger reduction in accuracy from the focal to non-focal task (10%) relative to controls (5%).[1] This shows that the results point in the same direction as hypothesised on the basis of the Rendell's et al. (2007) study. However, despite being twice the magnitude, the difference is too small to be interpreted as having any significance. Also, focality was not a within-subjects factor and therefore this difference could not be investigated any further.

It is possible that the event-based PM tasks used in Studies 4 and 5 were not cognitively demanding enough for the PM deficit to show in individuals with dyslexia or it may be that there is no PM deficit in event-based PM tasks. This is in line with the findings from the MIST (Study 3) which did not indicate PM difficulties in adults with dyslexia on event-based PM tasks but instead suggested deficits on time-based PM tasks. In Study 2 (PMQ) the participants themselves have also recognised that the most frequent PM failures (most significant difference between the two groups indicating largest PM deficit) are related to internally cued PM tasks. Time-based PM tasks depend strongly on internal cueing whereas event-based PM tasks involve external cues acting as a reminder (Einstein & McDaniel, 1990). Thus, these findings from the PMQ also indicated a greater time-based PM difficulty in individuals with dyslexia. This is also consistent with the argument that the task needs to be cognitively demanding for individuals with dyslexia to show a PM deficit. Time-based PM tasks have been argued to require more self-initiated monitoring compared to event-based PM tasks, which rely more on automatic retrieval processes (Einstein & McDaniel, 1990). The self-initiated monitoring is more cognitively demanding than automatic spontaneous retrieval processes (Einstein et al., 2005). Thus, it is possible that the ongoing tasks that were used in Studies 4 and 5 were not cognitively demanding enough to unmask any PM deficits in adults with dyslexia (Nicolson & Fawcett, 1990; already described in Chapter 2).

---

[1] Nevertheless, this is not a within-subject factor and therefore a firm conclusion cannot be drawn from this. The overlap in participants between focal and non-focal experiments (N=27) was insufficient to conduct a three-way ANOVA. Please see Appendix 6 for the juxtaposition of the focal and non-focal means tables.

Smith (2000, 2001; cited in Smith, 2008) found that having an event-based PM intention has a negative impact on the RT of the ongoing task. Smith argued that holding an event-based PM intention while being engaged in the ongoing task resulted in slower overall RTs in a lexical decision task when compared to not having to hold this PM intention. This supports the findings from Studies 4 and 5 where the RTs of all participants on the ongoing trials were generally slower in the PM block compared to the baseline block. Thus, it could be argued that these results supported the PAM theory (Smith, 2003) which argues that monitoring processes are employed in all event-based PM tasks and this may result in a cost to the ongoing task performance, as costs were visible in both the focal and non-focal tasks. Nevertheless, the data[2] revealed greater RTs in Block 2 compared to Block 1 under the non-focal condition. The difference between the RTs in Blocks 2 and 1 in the non-focal condition was significant (.002) whereas, in the focal condition it was approaching significance (.054). This is in line with Scullin et al. (2010) who argued that performing a PM task with a non-focal cue is more likely to result in costs to the ongoing task compared to PM task with focal cue. In addition, this finding supports the multiprocess view that non-focal PM tasks are more difficult and require monitoring processes compared to focal PM tasks, which are easier and rely on spontaneous retrieval processes. Nevertheless, the multiprocess framework of PM also highlights other variables which might be important in deciding whether individuals rely on spontaneous retrieval or monitoring processes to perform a PM task. For instance, the importance of the PM task, the number of different PM cues and the time interval between intention formation and execution can play a part in deciding which processes underpin PM performance (Einstein et al., 2005; McDaniel & Einstein, 2000). Further research could explore these factors in dyslexia but, based on the results of studies 4 and 5, dyslexics would not seem to have an event-based PM deficit (although it is obviously difficult to make conclusions based on null results).

6.2. Naturalistic and semi-naturalistic measures of event-based prospective memory

The rationale for carrying semi-naturalistic and naturalistic designs in the current thesis was to see how dyslexia-related PM problems might play out in more naturalistic settings and in everyday life. Semi-naturalistic and naturalistic paradigms to study PM are described in section 1.3.2. A number of semi-naturalistic and naturalistic investigations of event-based PM have been carried out previously to study PM. For instance, Masumoto et al. (2011) used a

---

[2] Please note that the trimmed data presented in Appendixes 3 and 4 did not show this effect of cost on the RT of ongoing trials. Breneires (2009) argues that the reason for this is that the data trimming procedure eliminates the cost of performing PM task visible in the performance on the ongoing trials.

naturalistic event-based PM task (among other tasks) in which two groups of older participants (in their 60s and 70s) had to call the experimenter after every breakfast, lunch and dinner for seven days. Dobbs and Rule (1987) employed a naturalistic and semi-naturalistic paradigms to investigate event-based PM and aging effects. They recruited five groups of participants ranging in age from 30 to 70+ years old. In the naturalistic task participants were required to note the exact date and time when they filled out the questionnaire that was given to them to complete at home. In the semi-naturalistic PM task participants needed to request a red pen when the experimenter asked them to draw a circle and a cube on a sheet of paper provided to them later on during the testing session (approximately after 20 minutes).

Another example of a semi-naturalistic task is the PM task used by Schmitter-Edgecombe et al. (2009) in which participants were required to remember to ask the examiner, eight times over the course of an hour, for a pill bottle in order to give pain medication to a friend. Participants were required to remember to do this after completion of task-liking rating scales. There were eight task-liking scales which were administered to participants one at the time after each of the eight ongoing tasks used in this paradigm. Therefore, there were eight occasions during which participants needed to ask the experimenter for the pill bottle. This task resembled a semi-naturalistic design as the PM tasks which closely mimicked everyday remembering but was administered in laboratory settings. This study found that individuals with mild cognitive impairment were significantly poorer at remembering prospectively compared to healthy control participants (older adults, age 50 or older).

It was hypothesised that individuals with dyslexia would be less able to remember prospectively compared to individuals without dyslexia. This was based on the data from the questionnaires used in the initial studies (Studies 1 and 2) as well as from anecdotal and empirical evidence about adults with dyslexia discussed in Chapter 2 (e.g. Augur, 1985; Varvara et al., 2014). The naturalistic and semi-naturalistic investigations conducted in this research involved varying periods of time over which the PM had to be maintained. It was expected that longer time intervals would result in lower abilities to remember prospectively due to memory decay processes and that these would be worse for dyslexics than non-dyslexics.

6.2.1. Study 6: Semi-naturalistic design (40 minutes time interval)

6.2.1.1. Introduction

This event-based semi-naturalistic task required a response to a PM cue (“The End” appearing on the computer screen) 40 minutes after the start of the laboratory testing. The cue appeared at the end of an event-based PM task (Study 4) which as a whole lasted 40 minutes. This task was an event-based PM task as it included a reminder about the PM activity in the form of a cue in the environment which in this case was “The End” screen. The semi-naturalistic task used was based on naturalistic principles but took place in a laboratory setting. It was expected that individuals with dyslexia would be less able to remember prospectively compared to age- and IQ-matched controls. This was established on the basis of the results from Study 1 and literature (e.g. Smith-Spark & Fisk, 2007; Einstein et al., 1997) described in Chapters 1, 2 and 3 which pointed towards PM problems in dyslexia.

6.2.1.2. Method

6.2.1.2.1. Participants

There were two groups of participants, 26 adults with developmental dyslexia and 24 controls matched for age and IQ. This study was attached to Study 4 and therefore the same participants were used. Please see the Participants section of Study 4 for information about the participants.

6.2.1.2.2. Materials

The Eye-Tracker (SR Research EyeLink) experiment builder software was used to record responses as this task was embedded in Study 4 which used the eye-tracker. Also, instructions written in the form of a laboratory notice on A4 paper were used. The instructions informed participants to press the “A” when they saw “The End” screen in order to save the data from the experiment.

6.2.1.2.3. Design

A score of one was given to participants who remembered to perform the PM task and a score of zero to those who did not.

A 2 x 2 Chi-square design was employed. The predictor variable in this study was the participant group (dyslexic vs. non-dyslexic) and the criterion variable was the response to the semi-naturalistic PM task (whether the participant remembered to press the keyboard or not).

6.2.1.2.4. Procedure

Informed consent was acquired from all participants prior to testing. In this study participants were informed at the beginning of the experimental session to press the “A” button on a keypad at the end of Study 4’s computer task. The participants were instructed that the results of the experimental task would not be saved if they did not press the “A” button at the end. The experimenter directed the attention of each participant to the instructions present in front of the participant in the form of a laboratory notice and reiterated those verbally. The notice stated that the “A” button needed to be pressed when participants saw “The End” screen. The writing “The End” appeared at the end of the experimental task in the centre of the screen and acted as the PM cue to trigger the intention of pressing the “A” button. Participants were debriefed at the end of the study.

6.2.1.3. Results

A Chi-square test of the significance of the difference in proportions was used to analyse the data. There was no significant difference between the observed and expected frequency of adults with dyslexia and without dyslexia in their PM task responses, $X^2 = .855$, df = 1, $p = .355$. Dyslexics or controls were not significantly more likely to forget to respond to the PM cue. The frequency counts are presented in Table 18.

Table 18: Frequency counts representing participants with and without dyslexia who remembered and did not remember to perform the 40 minutes event-based PM task.

	Participant group	
	Controls	Dyslexics
Did not remember	8	12
Remembered	16	14

6.2.1.4. Discussion

The results of a semi-naturalistic design investigating event-based PM memory with a delay of 40 minutes between intention formation and possibility of execution did not yield statistically significant differences between dyslexics and controls. This may be because the task was still carried out in the laboratory and therefore had lower ecological validity compared to the naturalistic task. Nevertheless, the direction of the results suggested greater proportion of individuals with dyslexia did not remember to perform the PM task.

Even though it is difficult to compare the semi-naturalistic event-based study to the experimental work on event-based PM, the PM deficit found in the semi-naturalistic task involving a delay of 40 minutes supports the results from Studies 4 and 5. Studies 4 and 5 involved 20 minutes time intervals between intention formation and execution. It is possible that the semi-naturalistic task did not produce significant differences between individuals with dyslexia and controls as the time delay was too short, similarly to the event-based PM experiments (Studies 4 and 5). In addition, the results from the PMQ (Study 2) as well as MIST (Study 3) also pointed towards a lack of PM deficits in dyslexia on items involving shorter time intervals. Namely, the Short-Term Habitual scale of PMQ was the only scale on which participants with dyslexia did not report having problems compared to controls. Similarly in MIST, the 2-minute and 15-minute time delay measures did not indicate a deficit in the dyslexia group.

It is also possible that the difference between the dyslexic and control participants was not significant in the semi-naturalistic as it was conducted in the laboratory (similarly to the experimental work) and participants were aware of the phenomenon of being studied. Kvavilashvili (1987) stated that PM is not easy to investigate as participants are aware of the phenomenon that is being studied and this may compromise ecological validity and make the results uninterpretable. On the other hand, it could be argued that the data from the naturalistic investigation involving a longer delay (one week) would provide more ecologically valid results.

6.2.2. Study 7: Naturalistic design (one week time interval)

6.2.2.1. Introduction

In this task participants needed to respond to a text message sent to them one week after the laboratory-based session reported in Study 4 by placing a missed call to the experimenter. The text message acted as a PM cue, making this activity an event-based PM task. It was expected that this task would result in PM deficits in dyslexia, as indicated by the questionnaire data (PRMQ and PMQ). The results from the PMQ (Study 2) indicated that participants perceived themselves to have problems with Long-Term Episodic PM and not with Short-Term Habitual PM type. Thus, together with the literature described in Chapters 1, 2 and 3 (e.g. Swanson, 2006; Hari and Renvall, 2001), it could be argued that individuals with dyslexia would have deficits in PM investigated though a naturalistic task involving a long time interval between intention formation and its execution.

6.2.2.2. Method

6.2.2.2.1. Participants

There were two groups of participants, adults with developmental dyslexia and controls matched for age and IQ. The selection and participant group matching criteria were the same as in previous studies and are described in section 4.1.2.1.1. Descriptive statistics regarding the gender and age of participants as well as t-tests comparing the two participant samples on the literacy and short-form IQ measures can be seen in Table 19.

Table 19: Descriptive statistics for gender and age and t-tests on literacy screening measures and short-form IQ.

	Gender		*Age (years)*		*Measure*: WORD Spelling Age	WORD Spelling Raw Score		DAST NWR Score		WAIS-IV Short-form IQ	
Group	Male	Female	Mean	SD	N<17 years	Mean	SD	Mean	SD	Mean	SD
Controls (N = 25)	6	19	23.40	4.70	0	44.88	1.67	92.20	3.23	107.18	9.64
Dyslexics (N = 26)	5	21	23.69	3.86	17	40.38	3.83	77.65	11.75	107.23	7.90

Independent samples t-test

	WORD Spelling Raw Score			DAST NWR Score			WAIS-IV Short-form IQ		
	t	*df*	*p*	*t*	*df*	*p*	*t*	*df*	*p*
	5.47	34.44	< .001	6.08	28.89	< .001	.019	49	.985

6.2.2.2.2. Materials

Instruction sheets were provided, along with an explanation of what was required in this naturalistic study. In addition, these included questions about mobile phone usage (see Appendix 8). A mobile phone with a new phone number and an email address was set up and dedicated for the sole use of this study. They were used to send and receive follow up emails, texts and calls (see Appendix 9).

6.2.2.2.3. Design

A 2 x 2 Chi-square design was employed. The predictor variable in this study was the participant group (dyslexic vs. controls) and the criterion variable was the response to the naturalistic PM task (whether the participant remembered to respond correctly by placing a missed call to the experimenter or not).

6.2.2.2.4. Procedure

Informed consent was acquired from all participants prior to testing. This task was administered at the end of the focal experiment. The experimenter explained to participants that this task was designed to test their memory for future intentions. Participants were informed that they would receive a text message (SMS) one week after the experiment. This text message contained their initials and participant number. The task involved remembering to call back the experimenter once the text message was received. Participants were requested to ring as soon as possible (preferably within 5 minutes) and to reply by calling the same telephone number from which the text message was received. In order to avoid any additional costs for the participants, they were told to wait for the phone to ring once and then end the call. Participants were asked not to make any reminders about the task e.g. calendar entries etc. This request was made in order for the task to rely purely on PM rather than on external reminders (important given the results of the PMQ).

After the instructions were provided the participants' understanding of the task requirements was checked. All participants reported that they understood what was required of them and explained the instructions to the experimenter. Participants were also asked whether their phones were pay monthly or pay-as-you-go phones in order to rule out all participants who may not be able to respond to the text message because of insufficient funds on their mobile phone accounts. If a participant reported to have a phone on a pay-as-you-go tariff, he or she was asked whether there were long periods of time when they had no money on their own account to make phone calls, but nobody reported this to be the case. These questions ensured (as far as possible) that all of the participants were able to respond to the text message when they received it. Additional questions were asked with regards to their competency in using mobile phone for calls, text messages and returning a call to a text message sender and all of the participants reported being competent in doing those tasks. All individuals taking part in this study were also asked about their mobile phone checking habit and all of the participants reported being frequent checkers of their mobile phones (on average, both groups of participants reported checking their mobile phones more than ten times a day). Verbal information was given to participants with regards to follow up emails. Namely, participants were told that they would receive an email with questions about the study they had just done and they were asked to answer them and send back to the experimenter via email. Each participant received a follow up email one week after the text message to which they had to respond.

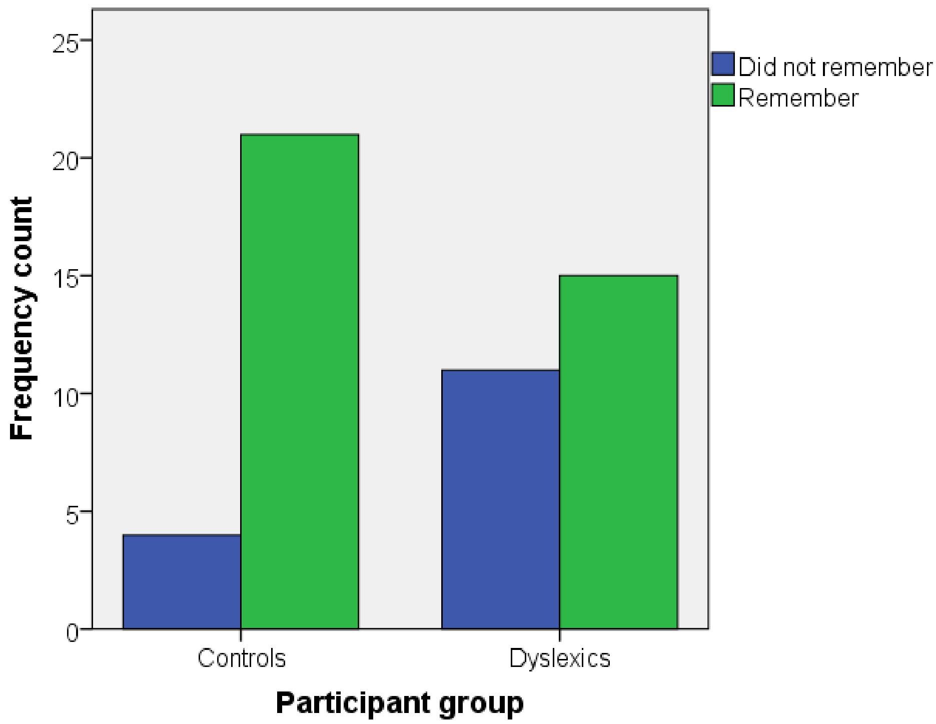
After being texted, all participants were sent a follow-up email checking whether the text message was received and asking them to confirm whether they had remembered the instructions for this task as well as how important the task was for them. Also participants were asked about reasons for responding later than five minutes to make sure that it was not the case that someone remembered about responding to this task but had no possibility of responding e.g. they were already on the phone or in an area with no reception and nobody reported this to be the case. Finally, participants were asked to reflect back and estimate how many times they thought about this task within the week time interval. Participants were debriefed at the end of the study.

6.2.2.3. Results

Three participants (one control and two dyslexics) who took longer than two hours to respond to the text message were considered as having forgotten about the PM task.

The results of Chi-square test revealed that there was a significant association between participant group and response to a one week delayed PM task, $X^2 = 4.25$, df = 1, $p = .039$. Adults with dyslexia were more likely to not remember about the PM activity, than to remember it, whilst individuals without dyslexia were more likely to remember about the PM task and less likely not to remember it. Figure 2 represents frequency counts for the two participant groups.

Figure 2: The association between participant group and performance on the one week naturalistic PM task.



The background data, acquired through the follow-up email, revealed a number of interesting findings. There were 23 dyslexic participants and 23 control participants who returned these questionnaires sent via email. First of all, the question from the follow-up email, asking participants to state whether they had remembered the instruction to respond to the text message by placing a missed call supported the findings from the Chi-square test carried out on the objective naturalistic measure. Namely, Fisher's exact test[3] revealed a significant association between participant group and self-reported remembering of the instruction, p = .023. The observed frequencies for this Fisher's exact test are displayed in Table 20. This test revealed that individuals with dyslexia reported not remembering the instruction requesting them to respond to the text message significantly more commonly than controls, who more frequently reported remembering this instruction.

---

[3] The Fisher's exact probability test was used as there were two categories in each of the two variables and two of the expected frequencies fell below 5, violating the rules of Chi-square.

Table 20: Observed frequencies representing self-reported remembering of the naturalistic PM instruction gained through follow-up email.

	Participant group	
Type of task	Controls	Dyslexics
Remembered	22	16
Did not remember	1	8

An independent samples t-test revealed that individuals with dyslexia (*M* = 7.61, *SD* = 2.86) did not report themselves to differ significantly in the amount of importance placed on the PM task compared to controls (*M* = 7.83, *SD* = 2.04), when asked after the task was completed, t (44) = .297, p = .768.

An unrelated t-test comparison showed that individuals with dyslexia (*M* = 5.39, *SD* = 2.02) did not report themselves to differ significantly in the number of times they thought about the PM task compared to controls (*M* = 6.35, *SD* = 1.64), t (44) = 1.76, p = .085.

6.2.2.4. Discussion

In this naturalistic design participants were less aware of the phenomenon studied as this investigation took place one week after the laboratory session under real life conditions and in an environment natural to the participant e.g. their own home. There were significant differences found between dyslexics and controls in this naturalistic design. Dyslexic participants were significantly more likely to forget to perform the PM task and controls were more likely to remember it. It may be claimed that there were more chances of forgetting the PM task in this naturalistic task compared to the semi-naturalistic PM task. Since having to remember about the PM task over one week creates more opportunities for memory decay processes to take place, compared a task where the PM intention needs to be held in memory for 40 minutes. This reasoning is in line with memory decay theory which proposed that memory fades with time (Thorndike, 1914). Tobias (2009) argued that the accessibilities of PM intentions decay at the same rate as retrospective memories. Furthermore, it could be argued that if participants are more likely to forget about the PM activity, they are also more likely to forget what was being studied when they received a text message from an unknown number with their initials and participant number. The prevailing question however is why individuals with dyslexia seem to display a greater decay of PM over longer time intervals compared to controls. It is possible that this is due to failure in the retrospective component.

Another explanation supporting the findings that individuals with dyslexia have problems with event-based PM in naturalistic settings involving longer time intervals, could be based on the claim of Jorm (1983). According to Jorm (1983) individuals with dyslexia make less use of rehearsal processes. Rehearsal has been described as a control process (Atkinson & Shiffrin 1968, 1971), as it relies on a successful use of rehearsal of the formed intention (e.g. periodically rehearsing the "to-be-remembered" intention or rehearsing the "to-be-remembered" task to oneself to memorise this intention). Thus, the reduced use of the rehearsal processes is a possible explanation for PM failures found in the current investigation. Furthermore, this explanation is in line with the phonological deficits in dyslexia (Snowling, 2000) which could result in reduced rehearsal. The claim related to reduced rehearsal could be also related to attentional monitoring (e.g. Smith & Bayen, 2004). Namely, if an individual rehearses the PM activity often, it could be stated that they also monitor more often for the PM cue. Thus, if individuals with dyslexia did not rehearse the PM intention as much as controls, this could lead to worse PM performance as it could be argued that they monitored less. However, Study 2 (PMQ) of the current investigation revealed that individuals with dyslexia reported using even more PM aiding strategies such as rehearsal compared to controls. This on the other hand, could demonstrate a coping strategy aiming to compensate for the PM deficit. Nevertheless, the findings from the background data (from the follow-up email) did not reveal significant group differences in the self-reported numbers of PM intention rehearsals. Namely, participants with dyslexia did not differ significantly in the number of times they thought about the PM intention over the one week time interval. It can be argued that thinking about the task involves an element of rehearsal. On the contrary to the results of Study 2 where individuals with dyslexia indicated to use more rehearsal processes, the inspection of the means from the follow up email could indicate that on average individuals with dyslexia rehearsed the PM intention fever times than controls. This reasoning would support the claim of Jorm (1983) that individuals with dyslexia make less use of rehearsal processes. However, it is unknown whether participants used different amounts of rehearsal straight after the instruction about the naturalistic task was given to them (whilst still in the laboratory) and whether all of the participants did not, as instructed, use any reminders; as this could have impacted on the results. There is also a possibility that the reporting of the amount of times that each participant thought about the task was inaccurate, as this was based on self-reports that were provided retrospectively rather than being recorded at the time and participants may have forgotten rehearsing it.

The results of this naturalistic study are consistent with the literature regarding dyslexia and PM covered in Chapters 1, 2 and 3. Namely, individuals with dyslexia would seem to have problems with timekeeping, organisation (e.g. Augur, 1985; McLoughlin, Fitzgibbon & Young, 1994; Miles, 1982; Tallal, 1985; Turner, 1997) and planning (e.g. Levin, 1990; Torgeson, 1977; Gilroy & Miles, 1996). Organisation, timekeeping and planning are related to PM as there are overlaps between these processes and PM (Macan et al., 2010); e.g. missing an appointment could be seen as a problem with timekeeping, organisation or planning, but also with PM.

6.2.3. General discussion (naturalistic measures)

The results from the naturalistic and semi-naturalistic event-based studies conducted as a part of this chapter suggested that whether there is or there is not a difference between the two participant groups, may depend on the length of the time interval between intention formation and the possibility of its execution. This is in line with the results from the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie & Maylor, 2000) used in Study 1 and prospective memory questionnaire (PMQ; Hannon, Adams, Harrington, Fries-Dias & Gibson, 1995) used in Study 2. In Studies 1 and 2 participants with dyslexia reported themselves to have a significantly poorer long-term PM compared to participants without dyslexia. These results were also confirmed by close friends and relatives in Study 1. In addition, long-term, self-cued or internally-cued types of PM tended to have the largest effect sizes.

Another explanation is that the findings from the semi-naturalistic investigation produced non-significant group differences because it was conducted in laboratory settings compared to the naturalistic study which produced significant group differences. This argument can be supported by Kvavilashvili (1987) who highlighted the impact of participant awareness about the studied phenomenon. Namely, participants were more likely to be aware of the studied phenomenon while in the laboratory compared to everyday life naturalistic conditions. In addition, there are many other day to day activities which draw on ones cognitive resources and this can also be an additional factor impacting on PM performance difference between these tasks. All of this together with the length of the time interval may have impacted on the results of this event-based investigation of PM.

6.3. Summary

The experimental work showed a cost to the ongoing task performance in PM blocks in both experiments (focal and non-focal). All participants were slower when responding to the ongoing trials in the PM blocks compared to the baseline blocks. This was interpreted in line with the literature (e.g. Smith, 2000; 2001, cited in Smith, 2008) as having to hold the PM intention in memory. The discrepancy between the RTs of Block 1 and 2 was more significant in the non-focal condition (.002) compared to the focal condition (.054). It was argued that these results were more in line with the PAM theory (Smith, 2003) rather than with the multiprocess theory (McDaniel & Einstein, 2000) However, different samples were used in both experiments and no direct comparisons could be made. The number of eye-fixations was generally significantly greater in adults with dyslexia indicating a possible coping strategy used for compensation of the PM deficit.

There were no event-based PM deficits in dyslexia found using experimental paradigms involving 20 minute time intervals between intention formation and execution. There were also no group differences in the accuracy of responses to the ongoing tasks. The data from the semi-naturalistic showed no significant group differences in the 40 minutes time interval employed in the semi-naturalistic event-based task. These results indicated that there were no event-based PM deficits in dyslexia when shorter-time intervals were used. However, it was argued that if more cognitively demanding tasks are used in the experimental work, event-based PM deficits may reveal itself in individuals with dyslexia (on the basis of the literature) indicating to problems with more cognitively demanding tasks (e.g. Nicolson & Fawcett, 1990), attention allocation (e.g. Smith-Spark & Fisk, 2007) and attentional resources (e.g. Hari & Renvall, 2001).

The only dyslexia-related problem with event-based PM found in this chapter was in the naturalistic task involving one week delay. It was argued that this could be related to the prolonged length of time-interval used in this task and insufficient use of memory rehearsal processes by individuals with dyslexia. It is possible that the smaller number of memory rehearsals could result in worse PM memory in dyslexia especially in a task involving one week time delay as it created greater opportunities for memory decay processes taking place.

The next stage of this thesis was to investigate time-based PM in dyslexia using experimental and everyday life conditions. This was to investigate if there are PM deficits in dyslexia when time-based PM tasks are employed. In addition, a manipulation of cognitive load was employed by adding cognitively demanding secondary ongoing tasks (visuo-spatially-loaded and phonologically-loaded). This explored cognitive load to see if PM tasks with higher cognitive load resulted in a drop of performance on PM tasks in dyslexia. This design was decided upon, following the reasoning presented in this chapter that the ongoing tasks employed in the event-based PM tasks were not cognitively demanding enough to result in a PM deficit in dyslexia. This claim was based on past research arguing that complex tasks result in task performance deficits in dyslexia when compared to controls (e.g. Nicolson & Fawcett, 1990; Smith-Spark & Fisk, 2007).

Chapter 7: Time-based prospective memory

7.1. Study 8: Experimental manipulation of cognitive load

7.1.1. Introduction

Time-based PM comprises of an activity which one intends to perform at a certain time in the future (Kliegel et al., 2001). Time-based tasks typically involve performing a PM activity at a specified clock time or after a certain amount of time elapses (e.g. 3 minutes). Examples of time-based PM tasks from everyday life involve remembering to pick up a child from school at 3pm or to return a call to a friend in half an hour. Under laboratory controlled conditions time-based PM tasks, like event-based PM tasks, need to be embedded in an ongoing activity (Einstein & McDaniel, 1990). This ongoing activity is performed in order to mirror real life conditions where breaking out from one activity (e.g. writing an essay) needs to be performed in order to engage in the intended activity (e.g. turn off the cooker after a certain amount of time; Einstein & McDaniel, 1996).

Time-based PM tasks involve monitoring processes as one needs to monitor for the appropriate time to perform the intended activity at the correct time (Einstein et al., 1995). However, there are no overt external PM cues reminding participants about PM activity or time monitoring behaviour (McDaniel & Einstein, 2007). Time monitoring is usually measured by observations of head turns by participants to check a clock or by recording key presses to reveal a clock on a screen. It is important that the checking of the clock involves an overt behaviour thus the clock needs to be obscured from immediate vision when carrying out the ongoing task (Harris & Wilkins, 1982; Einstein et al., 1995). This type of time checking involved in time-based PM tasks resembles the monitoring model suggested by Harris (1984; Harris & Wilkins, 1982). Harris proposed that individuals only check periodically for the right conditions to execute the intended action as opposed to continuous monitoring which would be too demanding on ones attentional resources. The periodic checking for the right conditions to perform PM task follow the Test-Wait-Test-Exit (TWTE; Miller, Galanter & Pribram, 1960) procedure where the Test is the checking for the appropriate moment to perform the PM activity. Thus, a participant performing a time-based PM task involving checking of time would check the time initially at test an early point to avoid being too late to perform the task. Once they have learned it is too early to perform the PM task, they would continue with the ongoing task (the “wait” period) until the next time check and so on “test” until the correct time has elapsed for the PM intention to be performed. Once the PM activity has been performed participants would stop monitoring ("exit") the environment for the correct time or continue to do so if there is another PM task. Research (e.g. Einstein et al., 1995) has shown that this time checking is strategic and increases in frequency closer to the time of the appointed PM activity.

A classic example of a time-based PM experiment is the Ceci and Bronfenbrenner (1985) study which investigated PM in 10 and 14 year old children. The time-based PM task was to take cupcakes out of the oven 30 minutes after being instructed to do so. While waiting for the cupcakes to be ready, children were engaged in a popular video game in an adjoining room. In this room there was a clock which allowed children to monitor the time. The authors were interested to see if the children remembered about the PM activity (i.e. to take out cupcakes from the oven after 30 minutes) and in the frequency and schedule of time monitoring activity. This study had an additional factor, namely the familiarity of the settings that the task was taking place. This factor was manipulated by Ceci and Bronfenbrenner where some children undertook this PM task in their own home (a familiar setting) and other children in laboratory settings (an unfamiliar setting). The results of this study showed that the unfamiliar laboratory setting led to higher PM performance (only one child forgot to take out the cupcakes from the oven) compared to performing the task at own home (42% of children either forgot to perform the PM activity or were late). Children also tended to check the time more in the laboratory settings compared to home settings. This supports the claim that monitoring processes improve PM performance (Smith, 2003) as children in the Ceci and Bronfenbrenner study monitored the time more in the laboratory and their PM performance was also better in the laboratory.

More recent studies (e.g. Einstein et al., 1995, 2005; Einstein & McDaniel, 1990) used a similar approach to study time-based PM under laboratory controlled conditions. For example, a study conducted by Einstein et al. (1995) required participants to press the F8 key every five minutes (six times as there were six five-minute segments to their experiment) whilst participants were engaged in a general-knowledge quiz (the ongoing task).

One of the key features of time-based PM tasks is the extent to which self-initiated processes are involved in PM retrieval. Craik (1986) proposed a framework of memory where he suggested that memory tasks can be ordered by the extent to which they require self-initiated processes in memory retrieval. Based on this theory memory retrieval is more dependent on processes initiated by the individual when there are fewer memory cues. For instance, in a task which has little in the way of memory cues, one is more likely to use strategies helping one to retrieve the information such as generating possible cues. Time-based PM tasks do not include any external cues which can aid the PM retrieval and thus require participants to initiate the retrieval themselves as no environmental event indicates the correct time for the performance of the intended action. Thus, according to McDaniel and Einstein (2007) at least laboratory based time-based PM is strongly self-initiated. Namely, one needs to actively monitor time for the appropriate moment to perform the intended action and this is based on self-initiated mental processes (d'Ydewalle, Bouckaert & Brunfaut, 2001). Thus, it can be argued that time-based PM tasks generally involve more self-initiated monitoring compared to event-based PM tasks relying more on automatic processes (Einstein & McDaniel, 1990).

The claim that time-based PM tasks involve generally more self-initiated monitoring processes compared to event-based PM task was supported by PM studies investigating PM performance differences on time- and event-based tasks in different age groups (d'Ydewalle et al., 2001; Einstein et al., 1995; Einstein & McDaniel, 1996; Park, Hertzog, Kidder, Morrell & Mayhorn, 1997). Namely, these studies indicated that time-based tasks showed age related deficits more consistently in comparison to event-based PM tasks. In addition, older adults have been found to perform significantly fewer time checks when performing time-based PM tasks (Einstein et al., 1995; Park et al., 1997). Einstein et al. (1995) argued that this occurred because of a problem with time estimation or a deficit in attentional resources in older adults.

On the contrary, a meta-analysis performed by Henry, MacLeod, Phillips and Crawford (2004) found that there was no significant difference between time- and event-based PM tasks in terms of age related deficits. This meta-analysis only used experiments conducted under laboratory controlled conditions, but these employed a number of different paradigms, tasks and stimuli. According to Phillips, Henry and Martin (2008) establishing the extent of age related deficits in PM tasks is not simply a matter of the type of PM (event- or time-based), but rather the extent to which tasks rely on strategic monitoring, the complexity of the task and memory load. Thus, it may be the extent to which tasks rely on strategic monitoring processes which is responsible for these differences in age related deficits between time- and event-based PM paradigms reported in different studies.

The findings of the meta-analysis conducted by Henry et al. (2004) are in line with the multiprocess view of PM (McDaniel & Einstein, 2000) and the claims of Craik's (1986) pivotal framework. This framework of memory stated that the fewer the cues are provided within a memory task the more the retrieval is dependent on processes initiated by the individual. On the basis of this it could be argued that focal event-based PM would be the type of PM task to rely least on self-initiated processes as there are clear PM cues and processing is supported by the ongoing task. The non-focal event-based PM cues would involve more self-initiated retrieval as the PM cues are not so obvious (as they are not supported by the processing of the ongoing task). Moreover, the time-based PM tasks would be the most reliant on self-initiated cues as environmental event cues are removed and the participant needs to monitor time by pressing a button (with the clock usually not visible in laboratory paradigms). This is also supported by the multiprocess view of PM which states that non-focal event-based PM tasks require more strategic monitoring compared to focal event-based PM tasks. Namely, strategic monitoring is self-initiated. The meta-analysis conducted by Henry et al. (2004) indicated that time-based PM tasks require similar amounts of strategic monitoring as non-focal event-based PM tasks. This is related to the extent to which a retrieval of a PM intention is self-initiated. Time-based tasks require similar self-initiated processes as the non-focal event-based PM tasks. Since in both types of task one needs to actively engage in monitoring of the environment for subtle cues to perform the intended activity (either monitor for non-focal cues or an appropriate time).

A low cognitive load in the ongoing task has been found to reduce age related deficits (e.g. Maylor, 1995). A study conducted by Martin and Schumann-Hengsteler (2001) investigated time-based PM in young and older adults. The authors manipulated the cognitive load of the ongoing activity. The study included three conditions with variations of the cognitive load of the ongoing task (low, medium and high). The PM task remained the same in all three conditions. The results of this study showed that PM performance was influenced by the cognitive load of the ongoing task. The authors of this study argued that PM performance is dependent on central processing capacities e.g. the CE (Martin & Schumann-Hengsteler, 2001). This study has also indicated that older adults had a very large deficit in PM in the high cognitive load condition. The finding showing a dramatic decrease in PM performance in older adults was interpreted to occur due to demands on cognition exceeding the resources available. The authors of this study argued that the extent of age related deficits in PM task is dependent on the extent to which a PM task makes demands on the processing resources of WM. These PM task demands are not only related to the PM activity but also to the overall task situation (including ongoing tasks). Martin and Schumann-Hengsteler concluded that limited WM resources are the underlying factor for inter-individual differences in PM tasks.

Even though dyslexics cannot be directly compared to older adults, they may have a similar underlying problem with attentional resources and WM. Based on the findings from previous studies it could be suggested that the PM deficit of individuals with dyslexia may be more subtle than in older adults, thus cognitively demanding tasks drawing heavily on attentional resources should reveal a PM deficit in individuals with dyslexia. This reasoning is in line with the CC hypothesis (Nicolson & Fawcett, 1994) which claimed that individuals with dyslexia can mask automatisation deficits in easier tasks, but not on more difficult tasks. In addition, attentional resources needed for time-based PM performance, in order to monitor the time, will have to be shared with the cognitively demanding ongoing tasks. McDaniel and Einstein (2000) stated that engaging or attention demanding ongoing tasks are likely to result in a demand for strategic monitoring resources. Strategic monitoring is based on self-initiated processes. A task which is reliant on self-initiated processing is more likely to be influenced negatively by manipulations of cognitive load as was found by Martin and Schumann-Hengsteler (2001). Thus, tasks employing ongoing activities involving high cognitive load could result in the strategic monitoring resources being insufficient for monitoring processes related to PM intention. Namely, if the ongoing task is engaging and demanding, the strategic monitoring resources could be used extensively and thus not enough monitoring resources could be left over for monitoring of time in order to perform the intended activity at the correct time. This could lead to worse PM performance in dyslexia in cognitively demanding PM tasks as individuals with dyslexia have been found to have deficits in WM (e.g. Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007). This reasoning is compatible with strategy deficits found in dyslexia (e.g. Torgeson, 1977; Levin, 1990). Namely, if individuals with dyslexia employ less efficient monitoring strategies, this could result in PM deficits as strategic monitoring has been argued to improve PM performance (Smith, 2003).

Considering that time-based PM tasks involve high levels of self-initiated processes and the data from the PMQ questionnaire (Study 2) and MIST (Study 3) indicated a time-based PM problem in dyslexia, the primary aim of this investigation was to examine whether there were time-based PM memory problems in dyslexia using a classical laboratory paradigm. In addition, the predicted deficit was based partly on the age related deficit found in time-based PM tasks (e.g. d'Ydewalle, Luwel & Brunfaut, 1999; Martin & Schumann-Hengsteler, 2001). Namely, that time-based PM performance relies on monitoring processes which require attentional resources that are claimed to decline with age (e.g. Craik & Byrd, 1982). Therefore, time-based PM tasks might produce a PM deficit in individuals with developmental dyslexia because individuals with dyslexia also have been reported to have CE impairments (e.g. Jeffries & Everatt, 2004; Smith-Spark et al., 2003; see Chapter 2 for discussion) and the CE is argued to be responsible for controlling the attentional system e.g. Baddeley (1986). The monitoring processes required for time-based PM tasks rely on attentional resources (Burgess & Shallice, 1997) and deficits in attentional resources have been found in both populations (older adults and individuals with dyslexia).

An experimental condition was created in order to investigate whether there were PM deficits in dyslexia in time-based PM paradigm. This condition (referred to as low cognitive load condition in this experiment) used a classical time-based experimental paradigm. In this task participants had to decide whether there were more pictures of living or dead well-known individuals as the ongoing task, and press the “A” button every three minutes from the start of the task as the time-based PM task.

The second main aim of this experiment was to investigate the effects of higher cognitive/WM load on PM performance in individuals with dyslexia compared to age- and IQ-matched controls. Considering problems with attention and WM in dyslexia (e.g. Smith-Spark & Fisk, 2007) it is plausible to hypothesise a PM deficit in individuals with dyslexia compared to controls, especially in tasks involving greater cognitive/WM load. For this reason a manipulation of cognitive/WM load was introduced.

The manipulation of cognitive/WM load involved one condition with low load and two versions of the high load condition, a phonologically-loaded and visuo-spatially-loaded. The low and high load conditions both employed primary ongoing tasks which involved deciding whether there were more living or dead celebrities shown on the screen. The PM task required a PM response to be provided every three minutes. Each of the two versions of the high ongoing task load condition employed an additional secondary ongoing task. One of the high ongoing task load conditions involved phonologically-based additional ongoing task and the other employed an additional visuo-spatial ongoing task. The two versions of the additional secondary ongoing task were used in order to investigate whether PM differences (if found) are evident on both non-phonologically and phonologically loaded ongoing tasks. The primary ongoing and PM tasks in both versions of the high ongoing task load condition were the same as in the low load condition. Both the phonologically-loaded and visuo-spatially-loaded secondary ongoing tasks used in the high ongoing task load conditions involved memory updating based on a similar principle to the letter updating task (Morris & Jones, 1990; also see Smith-Spark et al., 2003). The Morris and Jones letter updating task required participants to recall the six most recent consonants from lists of six, eight, ten and twelve items. Participants did not know how many items to expect. Thus, participants needed to first remember the six consonants which appeared and then needed to drop the least recent consonant and replace it with a new consonant every time a new item exceeding the primary six consonants appeared (in trials in which there were more than six items). The last six consonants had to be recalled in the order in which they appeared.

A very similar procedure to the one used by Morris and Jones was followed in the two versions of the high ongoing task load condition of the current study. In the phonologically-based additional ongoing task participants had to recall the last four correct answers to the primary ongoing task. The visuo-spatially-based secondary ongoing task involved recalling the last four positions of a red frame surrounding one of the pictures of well-known people in each trial. The visuo-spatial memory updating ongoing task created a demand on spatial memory as participants had to remember the locations of the pictures and recall them on a grid when prompted. The difficulty of both of these memory updating tasks was that participants did not know when to expect memory recall screens as this could be after four, five, six, seven or eight ongoing trials. Therefore, participants had to constantly update their memory to be able to correctly perform this task in addition to deciding whether there were more living or dead well-known people presented on the screen. In addition to this participants had to monitor the time in order to perform a PM-related activity every three minutes.

The high cognitive/WM load conditions involving additional memory updating ongoing tasks were hypothesised to result in greater decline in PM performance in individuals with developmental dyslexia compared to controls. This was hypothesised considering that PM performance is dependent on WM abilities (e.g. Smith et al., 2011) and WM has been found to be deficient in dyslexia. For instance Smith-Spark et al. (2003) compared the visuo-spatial WM of adults with developmental dyslexia to age- and IQ-matched adults without dyslexia and found that individuals with dyslexia had a significantly worse performance on dynamic spatial memory task under high memory updating load. The dynamic spatial memory task involved the recall of the location and order of the stimuli. In a different study Smith-Spark and Fisk (2007) demonstrated that adults with dyslexia had significantly lower complex span scores. The complex span task required participants to store and process the stimuli and thus suggested a domain-general CE impairment in dyslexia which was not restricted to phonological material. Following the reasoning presented by Smith-Spark and Fisk (2007) that there is a domain-general CE deficit in dyslexia it was hypothesised that PM performance of individuals with dyslexia would be impaired in both versions of the high ongoing task load conditions (i.e. involving phonologically-loaded and visou-spatially-loaded ongoing activities). It could be argued that the cognitive load created by the phonologically-based and visuo-spatially-based tasks would draw on domain-general CE resources, which are limited or deficient in dyslexia and that this would result in lower PM performance. This could be argued to be due to not enough cognitive resources left over to monitor the time and perform the primary ongoing and PM tasks. Such findings would support the claim of Smith-Spark and Fisk (2007) that there is a domain-general CE deficit in dyslexia.

Nevertheless, if group differences were found in the phonologically-loaded high cognitive load condition, it could indicate phonological difficulties in dyslexia e.g. as stated by the phonological deficit hypothesis (Snowling, 1995). It could be argued that not only significant group differences on the phonologically-based secondary ongoing task would be indicative of this, but also group differences on the primary ongoing or PM tasks. Since, the phonologically-based processing demands of the ongoing activity could interfere with PM or primary ongoing task performance in individuals with dyslexia. Namely, if there are phonological deficits in dyslexia, more attention would need to be allocated to the phonologically-based task in order to have a comparable to normal performance on this task. This in turn could lead to fewer cognitive resources being available to monitor the time and perform the PM and primary ongoing tasks.

On the basis of the results from Studies 2 (PMQ) and 3 (MIST) as well as the literature (e.g. Jeffries & Everatt, 2004), it was hypothesised that individuals with dyslexia would have a time-based PM deficit when compared to controls. Considering WM defects in dyslexia (e.g. Smith-Spark & Fisk, 2007) and that PM performance is dependent on WM abilities (e.g. Smith et al., 2011), it was also hypothesised that greater cognitive/WM load created by the means of ongoing task would result in greater PM deficits in dyslexics. It was assumed that regardless of the domain in which the load was created it would have a negative impact on task performance of adults with dyslexia.

7.1.2. Method

7.1.2.1. Participants

Data were collected from two groups of university students (total N = 49): adults with dyslexia and adults without dyslexia. All of the participants were native English speakers and aged between 18 and 35 years old. A total of 24 individuals with dyslexia and 25 without dyslexia were recruited. Similarly to previous studies conducted in this thesis participants with and without dyslexia were matched for age and IQ. The two participants groups were also differentiated on literacy measures. For more details about this please see section 4.1.2.1.1. The descriptive statistics and unrelated t-tests comparing the two participant groups are included in Table 21.

Table 21: Descriptive statistics for gender and age and t-tests performed on literacy screening measures and short-form IQ.

	Measure												
	Gender		*Age (years)*		WORD Spelling Age	WORD Spelling Raw Score		DAST NWR Score		WAIS-IV Short-form IQ			
Group	Male	Female	Mean	SD	N<17 years	Mean	SD	Mean	SD	Mean	SD		
Controls (N = 25)	6	19	23.44	4.51	0	45.36	1.78	93.20	2.96	110.24	10.41		
Dyslexics (N = 24)	6	18	24.67	5.16	12	40.88	3.66	78.88	9.81	110.59	9.71		

Independent samples t-test								
WORD Spelling Raw Score			DAST NWR Score			WAIS-IV Short-form IQ		
t	*df*	*p*	*t*	*df*	p	*t*	*df*	*p*
5.42	32.95	< .001	6.86	27.00	< .001	.121	47	.904

7.1.2.2. Materials

Three experimental conditions were created using E-Prime 2.0 Professional for Windows (Psychology Software Tools, Inc., Sharpsburg, PA). The first experimental condition involved an ongoing task and a PM activity. The ongoing task was to judge whether there was more living or dead famous individuals presented on the screen. The PM task involved pressing a button every 3 minutes. The second and third experimental conditions, in addition to the ongoing and PM tasks, involved a secondary ongoing task involving WM. One condition involved a phonologically-loaded WM ongoing task and the other conditions involved a visuo-spatially-loaded WM ongoing task. Participants were allowed to check how much time passed since the start of the task.

Participants sat in front of a 19” computer screen (Hanns.G HX191D) connected to a RM 8030 PC. A 15” RM laptop was placed behind participants on a filing cabinet forming a part of the usual furnishing of the room. Participants responded to the task using a purpose-built push button box which had eight buttons. This push button box had eight buttons positioned in three rows with three buttons in the top two rows and two in the bottom row. The top two rows mimicked the two by three grid in which the stimuli were presented. These buttons were only used for the purpose of the visuo-spatial additional ongoing task (see below). The bottom row included two labelled buttons. The two labels were LIVING and DEAD and were colour coded (living - green; dead - red). The same colour coding was used in the instruction screens. This push button box was connected to both the PC on which the ongoing task was run and to the laptop (placed behind participants) on which PM responses had to be made. This allowed the clocks of the two computers to be synchronised. This was achieved by pressing a side button positioned at the top of the push button box which started the running of the two tasks (ongoing and PM) at the same time. Responses on the laptop placed behind participants were recorded using the laptop’s keyboard.

The stimuli (24 celebrities; 12 living and 12 dead) were chosen on the basis of responses provided by a panel consisting of 26 native English speakers (all of whom were university students and British Citizens; 21 females, five males) between the ages of 18 and 35 years old (mean age = 21.96 years, SD = 4.75). The characteristics of the panel with regards to age, gender and occupation matched closely the characteristics of the participant group for this experiment. Each person from the panel was asked to provide five very well-known living and five very well-known dead celebrities that would be the most recognised by people in the United Kingdom. The data from the panel was collected by the means of an online survey designed using the Qualtrics Research Suite (Qualtrics, Provo, UT). The most frequently occurring names within each list of celebrities (living and dead) were selected to form the stimuli. Twenty-four greyscale images of well-known celebrities which are well recognised by people living in United Kingdom were used (for names, see Appendix 7). These pictures were 256 x 256 pixels in size and half of them showed living celebrities where the other half were deceased. There were 12 practise trials which employed the same stimuli as were used for the purpose of experimental conditions. All experimental conditions used the same stimuli.

Instruction screens were used for the primary and secondary ongoing tasks and for the different PM tasks. The instructions for the primary ongoing tasks revealed to participants all of the famous faces used throughout the task. The phonologically-loaded ongoing task also employed a memory recall screen consisting of four rows each with two empty squares. The top row was labelled “least recent” and the bottom row was labelled “most recent”. The squares were highlighted in green when selected. The visuo-spatially-loaded ongoing task also employed a memory recall screen consisting of two rows each with three empty squares. The layout of the squares in the memory recall screen resembled the layout of grid in which the famous faces were shown in the primary ongoing task. This task employed the additional six buttons of the push button box also representing the same (two by three) layout of the ongoing task presentations.

7.1.2.3. Design

This experiment comprised of three conditions which manipulated cognitive/WM load. There was one condition which involved low cognitive load and two versions of a task with higher cognitive load (phonologically-loaded and visuo-spatially-loaded). In the low participants performed simple ongoing and PM tasks. Each of the two conditions representing higher cognitive load employed an additional ongoing task which increased the involvement of cognitive/WM resources. One involved a phonologically-loaded memory updating additional ongoing task and the other involved an additional visual-spatial memory updating ongoing task.

All three conditions involved primary ongoing and PM tasks. The responses to the primary ongoing task had to be provided on the PC placed in front of participants and four PM tasks to which responses had to be made on the laptop placed behind participants. The ongoing task presented on the PC consisted of ongoing trials where participants had to decide whether there were more living or dead celebrities within each trial. Each trial consisted of six pictures presented on a black computer screen in two parallel horizontal rows (three pictures in each row) with a 0.5cm space between each other. The order of the pictures on the screen was randomly assigned based on a random number allocation rule. Each trial consisted of either five pictures of living celebrities and one dead or four living and two dead and the opposite ways around (i.e. five-one, one-five, four-two and two-four). These splits were equated across all trials. The presentation of trials was randomised and there was a 30 second time limit to provide a response to each trial. If a response was provided before the 30 seconds had passed the task moved on to the next trials. The task also moved on to the next trial when there was no response provided within 30 seconds. The tasks in all three conditions were programmed to stop after 14 minutes. The stimuli lists were looped so that if a participant got through all trials before 14 minutes had elapsed, the list would start again from the beginning (in random order). This primary ongoing task involved a total of 212 trials in the low cognitive load condition and 150 in the two versions of the task involving high cognitive load. The smaller number of ongoing trials in the two tasks involving high cognitive load was due to the additional phonologically-/visuo-spatially-loaded trials of the secondary ongoing tasks. There were 12 practise trials with feedback in all three conditions. Each of the two versions of the high ongoing task load condition embedded two additional memory recall practise trials in the practise run.

All three conditions involved a time-based PM task which included four PM activities where participants had to press an “A” key on the keyboard of the laptop placed behind them every three minutes i.e. at 3 minutes, 6 minutes, 9 minutes and 12 minutes from the start of the experiment. This task involved breaking out from the ongoing activity which was performed on the PC in front and turning around to perform the PM action i.e. press the “A” key at the appropriate time. Participants were not allowed to have their personal watches visible, but were able to check how much time had elapsed since the start of the experiment by pressing the space bar of the laptop placed behind them. There were no restrictions on how many times participants could check the time. This task was programmed to stop at the same time as the ongoing task (after 14 minutes excluding the practice trials and instructions).

The high load condition with the phonologically-loaded additional ongoing task involved the same primary ongoing and PM tasks as were employed in the low load condition. There was an additional (secondary) phonologically-based memory updating task which was embedded in the primary ongoing task. This secondary ongoing task involved remembering and providing the last four correct answers when prompted (e.g. living, dead, living, living). The answers had to be recalled in the same order in which they were initially provided. This task engaged memory updating processes as the memory recall screens appeared on the computer screen pseudo-randomly, after four, five, six, seven or eight ongoing trials. There were 25 memory recall screens where the last four answers had to be provided and these were time limited to 40 seconds per memory recall screen.

The high load condition involving visuo-spatially-loaded additional ongoing task used the same primary ongoing and PM tasks as were employed in the low load condition. The visuo-spatial memory updating task was embedded in the primary ongoing task. This additional ongoing task involved remembering and recalling the locations of the last four pictures of the primary ongoing task which were surrounded by red frames. In each trial of the primary ongoing task one from the six pictures of celebrities was surrounded by a red frame. The location of this frame changed randomly so that in each trial a picture in a different position had a red frame around it. The pictures surrounded by red frames had to be recalled in the same order as they appeared. To enable participants to record these responses there were six buttons on the push button box which resembled the two by three grid in which the pictures were presented in the trials. An empty grid was visible during the recall screen and the button presses highlighted the corresponding empty box in the grid.

Each time a response was made to the PM tasks in all conditions, the screen of the laptop (normally black) flashed green for 600ms. Prospective memory responses were scored where each correct response to the PM task was given a score of two. A score of zero was given for responses which were provided earlier than 10 seconds from the time of each PM activity or after 10 seconds from that time (+/-10 seconds) creating a 20 seconds time window during which a PM response could be given. The same time window for correct time-based PM responses was used by Mioni and Stablum (2014). A score of one was given to incorrect content of PM responses which were still performed at correct times (e.g. pressing "B" button instead of

“A” or providing the incorrect year). The scoring procedure used within this task was similar to that employed in the MIST (Raskin, 2004).

The administration of the three time-based PM conditions was counterbalanced over two testing sessions conducted on different days. Each session comprised either of one or two experimental tasks with other screening and short-form IQ measures placed in between the tasks in order to minimalise task interference.

7.1.2.3.1. Data analysis

The PM accuracy, ongoing accuracy and ongoing RT data acquired from the ongoing task load manipulation were analysed using a 2 x 3 mixed measures ANOVAs with the between-subjects factor of participant group (individuals with and without dyslexia) and the within-subjects factor of cognitive load (low, high phonologically-loaded and high visuo-spatially-loaded).

The additional ongoing tasks involving memory updating were analysed using a mixed measures 2 x 2 ANOVA with the between-subjects factor of participant group (individuals with and without dyslexia) and the within-subjects factor of task type i.e. phonologically-based and visuo-spatially-based. This analysis was performed in order to investigate if there were any dyslexia related deficits visible on the secondary ongoing tasks of the high cognitive load condition.

7.1.2.3.1.1. Time checks

Individuals with dyslexia have been reported to have strategy deficits (e.g. Torgeson, 1977; Levin, 1990) and this could lead to PM differences. Namely, if individuals with dyslexia employ less efficient monitoring strategies, this could result in PM deficits as strategic monitoring has been argued to improve PM performance (Smith, 2003). In order to ensure that there were no significant group differences in time monitoring strategies, a 2 x 3 x 6 mixed measures ANOVA was performed with participant group (dyslexics and controls) as the between-subjects factor and cognitive load of ongoing tasks (low, high phonologically-loaded and high visuo-spatially-loaded) and time checks in every sextile (time checks performed in the

1st, 2nd, 3rd, 4th, 5th and 6th 30 seconds before each PM response was required) as the within-subjects factors.

7.1.2.4. Procedure

Informed consent was acquired from all participants prior to testing. Background information about participants (age, gender and dyslexia status) was collected before the administration of the short-form IQ and literacy measures. Two of the scales used for the short-form IQ together with two of the experimental conditions were administered in the first experimental session and the remaining two in the second (the order was fully counterbalanced). For the experimental tasks participants were asked to sit in front of a computer with a laptop placed directly behind them on a small filing cabinet. Participants saw instructions displayed on the screen which explained what was required of them for the ongoing task. Those instructions asked participants to decide as quickly and as accurately as possible whether the majority of the six well-known individuals were living or dead. Participants were instructed to use the two buttons labelled DEAD (a button positioned on the left hand side of the push button box) and LIVING (a button positioned on the right hand side) in order to respond to this task. In the high phonologically-loaded and high visuo-spatially-loaded conditions participants where given the instructions about the additional, ongoing tasks (procedure for these tasks is described in the latter part of this section).

After the instruction for the ongoing task participants saw a final instruction screen including 24 pictures used within the task dividing the photographs of celebrities into two columns. There were 12 photographs of dead celebrities presented in a column positioned on the left hand side of the screen and 12 photographs of living celebrities presented in a column on the right hand side of the screen to match the sides of the response buttons (DEAD on the left and LIVING on the right side of the push button box). Prior to the start of the practice trials participants confirmed that they were familiar with the celebrities and aware which celebrities are living and which dead. After this participants engaged in 12 practice trials (including memory checks in high phonologically-based and high visuo-spatially-based conditions) where feedback was provided after each trial so that participants could learn how to respond to the task. The experimenter was present during the practice trials to further clarify instructions if not understood and to answer any possible questions.

After the practice trials, participants were shown an instruction screen explaining that the actual experimental condition would involve the same ongoing task to be performed on the PC placed in front of them, but that an additional PM task needed to be performed on a laptop placed behind them. Participants were informed that they would need to press the “A” key on the keyboard of the laptop placed behind them every three minutes in each of the three conditions.

Participants were also instructed that they could check how much time had elapsed since the start of the experiment by pressing the space bar on the laptop placed behind them. Participants were specifically told that the timer would start at 00:00 to avoid any possible confusion. After this instruction the experimenter synchronised the two computers and started the tasks. The experiment ran for 14 minutes and participants were allowed to check the timer as many times as they liked. Each time a participant logged the PM response the screen of the laptop (normally black) flashed green for 600ms.

In the additional phonologically-based ongoing task the instructions asked participants to use the buttons labelled DEAD and LIVING on the push button box to record the sequence of the last four correct responses (starting from the least recent and finishing with the most recent answer). The memory recall screen consisted of eight boxes in two vertical lines, four on the left hand side of the screen and the other four on the right hand side of the screen. At the top of each column there was a label stating DEAD above the column on the left hand side and LIVING above the column on the right hand side. The locations of the descriptors on the screen matched the locations of the labels on the push button box. The boxes on the screen were highlighted in green as each participant attempted to record the last four responses that they had made. Participants did not know when to expect memory recall screens as this could be after four, five, six, seven or eight ongoing trials.

The additional ongoing task used in the high visuo-spatially-loaded condition included similar instructions as the additional ongoing task used in the phonologically-loaded condition. The difference in this task was that participants were instructed to use the six buttons (in two rows) on the push button box to indicate the positions of the last four pictures which appeared with a red frame around it starting from least recent and finishing with the most recent position. The memory recall screen consisted of six boxes (i.e. a 2 x 3 grid) and the boxes on the screen highlighted in green as each response was made. Participants were debriefed at the end of the study.

7.1.3. Results

7.1.3.1. Excluded Participants

For inclusion, participants were expected to achieve an accuracy of at least 75% correct responses on the ongoing task of the low load condition which served the function of a baseline condition used for comparisons with higher cognitive load conditions. The 75% exclusion criterion was only applied to the simple PM design in order to avoid the potential elimination of possible cost effect caused by higher cognitive load (manipulated by the ongoing tasks). This in turn could minimalize or even eliminate possible group effects of load on PM or ongoing tasks performance. A similar procedure was performed in the event-based experiments where the exclusion criteria were only used for the baseline conditions. This procedure is in line with Breneiser's (2009) argument that data trimming eliminates the cost of performing PM task visible in the performance on the ongoing trials. All participants achieved at least 75% accuracy on the ongoing task of low load condition (the lowest accuracy was 77%). This suggested that all participants understood the instructions and engaged well with the tasks in general.

Six members of the control group were removed from the data set and replaced due to showing literacy characteristics not in the normal adult range. Also, five participants (two individuals with dyslexia and three controls) whose IQ was below 90 were also replaced. One participant with dyslexia withdrew from the experiment. The number of participants reported in the Participants is the number tested after removing those who did not meet the selection criteria or withdrew.

7.1.3.2. Prospective memory accuracy

The results in Table 22 show descriptive statistics for the PM accuracy data acquired from low, high phonologically-loaded and high visuo-spatially-loaded conditions.

Table 22: Descriptive statistics for PM accuracy data in low, high phonologically-loaded and high visuo-spatially-loaded conditions.

Means	Prospective memory accuracy (max. score = 8)			
	Controls		Dyslexics	
Condition	*M*	SD	*M*	SD
Low	4.64	2.22	3.75	2.38
High phonologically-loaded	4.80	2.52	3.42	2.08
High visuo-spatially-loaded	4.80	2.45	2.79	2.59

The PM accuracy data from the low, high phonologically-loaded and high visuo-spatially-loaded conditions were subjected to a 2 x 3 ANOVA. There was a significant main effect of participant group, F (1, 47) = 8.27, p = .006, η_p^2 = .150. An inspection of means indicated that individuals with dyslexia had lower PM accuracy overall than controls. The effect of cognitive load, F (2, 94) = .544, p = .582, η_p^2 = .011 was not significant. There was also no significant interaction between participant group and cognitive load, F (2, 94) = .970, p = .383, η_p^2 = .020.

7.1.3.3. Ongoing trials

7.1.3.3.1. Reaction time

Mean reaction times to the ongoing trials in low, high phonologically-loaded and high visuo-spatially-loaded conditions are displayed in Table 24.

Table 24: Descriptive statistics for reaction time data from ongoing tasks of low, high phonologically-loaded and high visuo-spatially-loaded conditions.

Means	Ongoing task mean reaction times (ms)			
	Controls		Dyslexics	
Condition	*M*	SD	*M*	SD
Low	3151.31	913.94	3860.79	1097.90
High phonologically-loaded	4188.83	1372.271	5102.96	1926.76
High visuo-spatially-loaded	5134.36	1766.82	6358.71	2083.83

The 2 x 3 mixed measures ANOVA conducted on the RT data from ongoing trials of the three cognitive load conditions showed a significant main effect of participant group, F (1, 47) = 5.68, p = .021, η_p^2 = .108. These results showed that there were significant differences in RT between dyslexics and controls regardless of cognitive load condition. There was also a main effect of cognitive load, F (2, 94) = 73.16, p < .001, η_p^2 = .609 which indicated that participants regardless of group membership differed in their RTs to the different cognitive load conditions. Post hoc Bonferroni comparisons showed that participants' RTs differed significantly between low and high phonologically-loaded (p < .001), high phonologically-loaded and high visuo-spatially-loaded (p < .001), and between low and high visuo-spatially-loaded (p < .001) conditions. The interaction between the two factors was not significant, F (2, 94) = .979, p = .379, η_p^2 = .020.

7.1.3.3.2. Accuracy

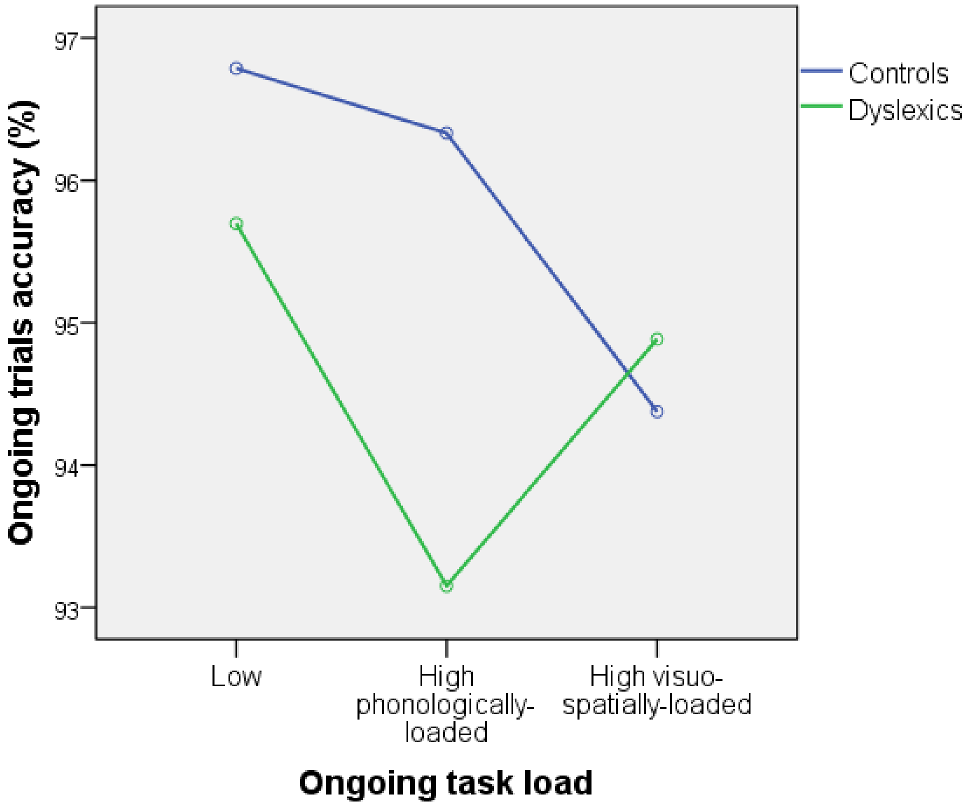
Table 23 includes descriptive statistics for accuracy (%) data acquired from ongoing trials of low, high phonologically-loaded and high visuo-spatially-loaded conditions. This analysis included only the primary ongoing tasks in which participants needed to decide whether there were more living of dead celebrities presented in each array. The data from the additional ongoing tasks (phonologically- and visuo-spatially-based) were analysed separately.

Table 23: Descriptive statistics for accuracy of ongoing trials in low, high phonologically-based and high visuo-spatially-based conditions.

Means	Ongoing task accuracy (%)			
	Controls		Dyslexics	
Condition	*M*	SD	*M*	SD
Low	96.79	4.29	95.70	5.38
High phonologically-loaded	96.33	3.91	93.15	6.38
High visuo-spatially-loaded	94.38	5.78	94.89	4.93

The 2 x 3 mixed measures ANOVA conducted on the accuracy data from the ongoing trials of low, high phonologically-loaded and high visuo-spatially-loaded conditions showed no significant effect of participant group, F (1, 47) = .942, p = .337, η_p^2 = .020. There was a significant main effect of cognitive load, F (2, 94) = 4.19, p = .018, η_p^2 = .082 which indicated that participants differed in their ongoing tasks accuracy in the different cognitive load conditions. Post hoc Bonferroni comparisons indicated that participants' accuracy only differed significantly between the low and high phonologically-loaded conditions (p = .002). There were no significant differences between high phonologically-loaded and high visuo-spatially-loaded conditions (p = 1.00) nor between low load and high visuo-spatially-loaded conditions (p = .068). There was a significant interaction between participant group and cognitive load, F (2, 94) = 4.42, p = .015, η_p^2 = .086. Figure 3 shows the interaction between the two factors. Post hoc unrelated t-tests conducted on the ongoing task data acquired from the low cognitive load condition showed no significant differences between dyslexics and controls, t (47) = .785, p = .437. There was a significant group difference in the high phonologically-loaded condition, t (37.86) = 2.10, p = .043. Inspection of means indicated that individuals with dyslexia were less accurate on the primary ongoing task trials compared to controls. There was no significant group difference in the high visuo-spatially-loaded condition, t (47) = .331, p = .742.

Figure 3: Group x condition interaction plot for mean ongoing task accuracy.



7.1.3.4. Updating memory tasks (phonologically- and visuo-spatially-based tasks)

Table 25 displays the descriptive statistics for the two versions of the memory updating secondary ongoing tasks used in high phonologically-loaded and high visuo-spatially-loaded conditions.

Table 25: Descriptive statistics for secondary ongoing tasks used in high phonologically-loaded and high visuo-spatially-loaded conditions.

Means	Accuracy of memory updating tasks (%)			
	Controls		Dyslexics	
Condition	*M*	SD	*M*	SD
High phonologically-loaded	76.11	12.25	71.75	10.34
High visuo-spatially-loaded	57.02	23.99	56.93	22.33

The results from a mixed measures 2 x 2 ANOVA conducted on memory span accuracies (%) acquired from the additional ongoing tasks used in the high phonologically-loaded and high visuo-spatially-loaded conditions showed that there was no significant effect of participant group, F (1, 47) = .225, p = .616, η_p^2 = .005, but there was a significant effect of task type, F (47) = 37.30, p < .001, η_p^2 = .442. The means revealed that the participants performed worse on the visuo-spatially-based memory updating task compared to the phonologically-based version. There was no significant interaction between the two factors, F (1, 47) = 594, p = .445, η_p^2 = .012.

7.1.3.5. Time checks

Table 26 shows the descriptive statistics from the total time checks made by both groups of participants in the low, high phonologically-loaded and high visuo-spatially-loaded conditions.

Table 26: Descriptive statistics from the total number of time checks in low, high phonologically-loaded and high visuo-spatially-loaded conditions.

Means	Number of time checks			
	Controls		Dyslexics	
Condition	*M*	SD	*M*	SD
Low	10.64	3.49	8.75	3.53
High phonologically-loaded	11.76	4.41	10.04	5.28
High visuo-spatially-loaded	11.60	3.76	8.96	6.34

A 2 x 3 x 6 mixed measures ANOVA was performed on the time check data across the three cognitive load conditions. There was no significant effect of participant group, F (1, 47) = 3.70, p = .060, η_p^2 = .073. However, it is worth noting that this effect was approaching significance and that participants with dyslexia (M = 9.25), on average, performed fewer time checks compared to controls (M = 11.34). The effect of cognitive load, F (2, 94) = 1.21, p = .301, η_p^2 = .025 was not significant showing that regardless of group participants time checks did not differ significantly in the different cognitive load conditions. There was a main effect of sextile, F (5, 235) = 57.65, p < .001, η_p^2 = .551. Post hoc Bonferroni comparisons indicated that the majority of the sextiles differed significantly from one another. The sextiles which differed between each other at the p < .001 level were: 1st and 2nd, 1st and 3rd, 1st and 4th, 1st and 6th, 2nd and 3rd, 2nd and 4th, 2nd and 5th, 2nd and 6th, 3rd and 5th, 3rd and 6th, 4th and 6th, and 5th and 6th. The difference between 4th and 5th sextiles was also significant (p = .027). There were also two non-significant comparisons, these were between the 1st and 5th (p = 1.00), and 3rd and 4th (p = .271) sextiles. The mean time checks were slightly higher in the initial sextile and dropped to their lowest mean in the second sextile. After the second sextile the means of time checks rose gradually up until the last sextile (6th) where they reached the highest mean value. Figures 4, 5 and 6 represent the time checks patterns in the three ongoing task load conditions.

The two-way interaction between group and load was not significant, F (2, 94) =0.94, p = .911, η_p^2 = .002. There was no significant two-way interaction between sextile and participant group,

F (2, 47) = .476, p = .794, η_p^2 = .010. The two-way interaction between load and sextile was also not significant, F (5, 235) = .685, p = .739, η_p^2 = .014. The three-way interaction between group, load and time checks was not significant, F (5, 235) = 1.75, p = .067, η_p^2 = .036.

Figure 4: Time monitoring pattern of individuals with and without dyslexia in low cognitive load condition.

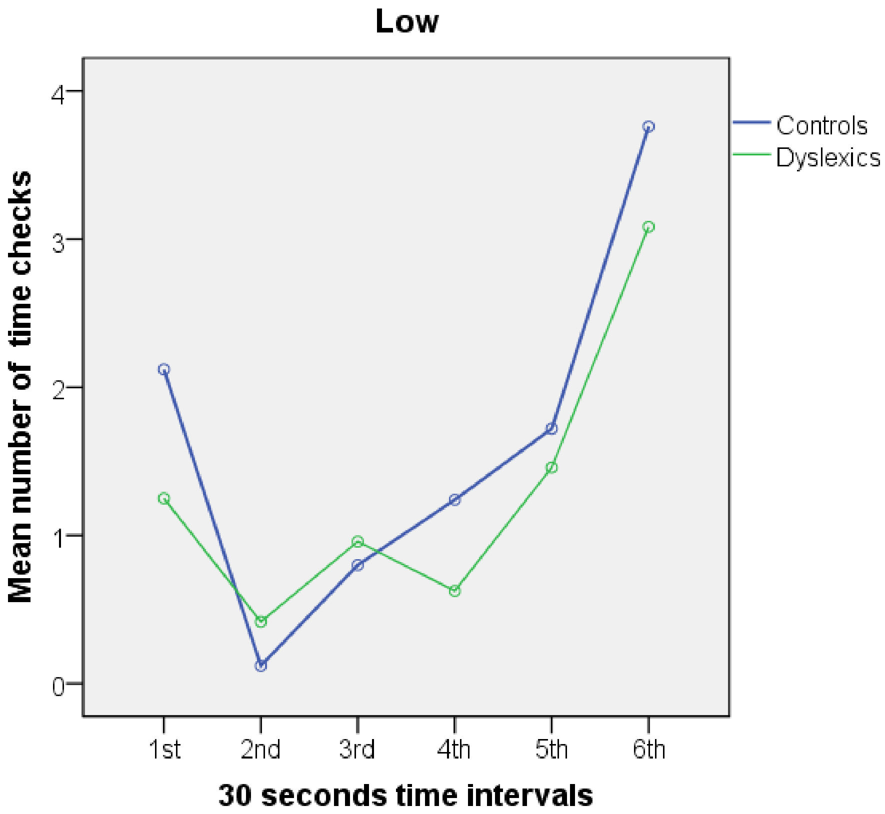


Figure 5: Time monitoring pattern of individuals with and without dyslexia in high phonologically-loaded condition.

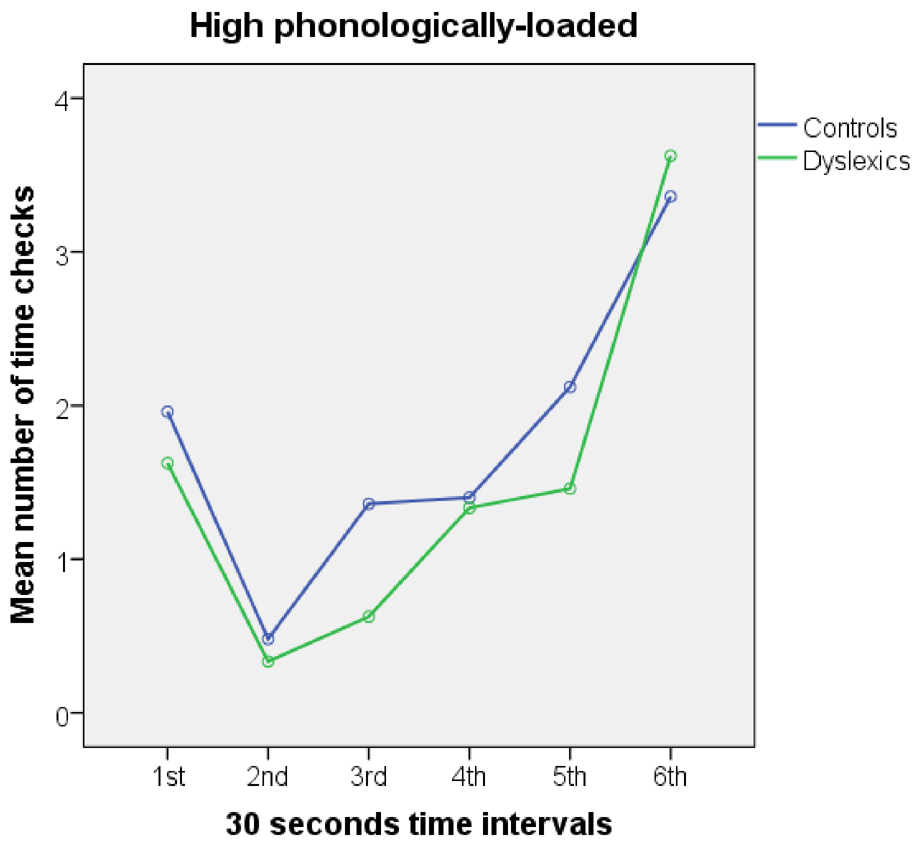
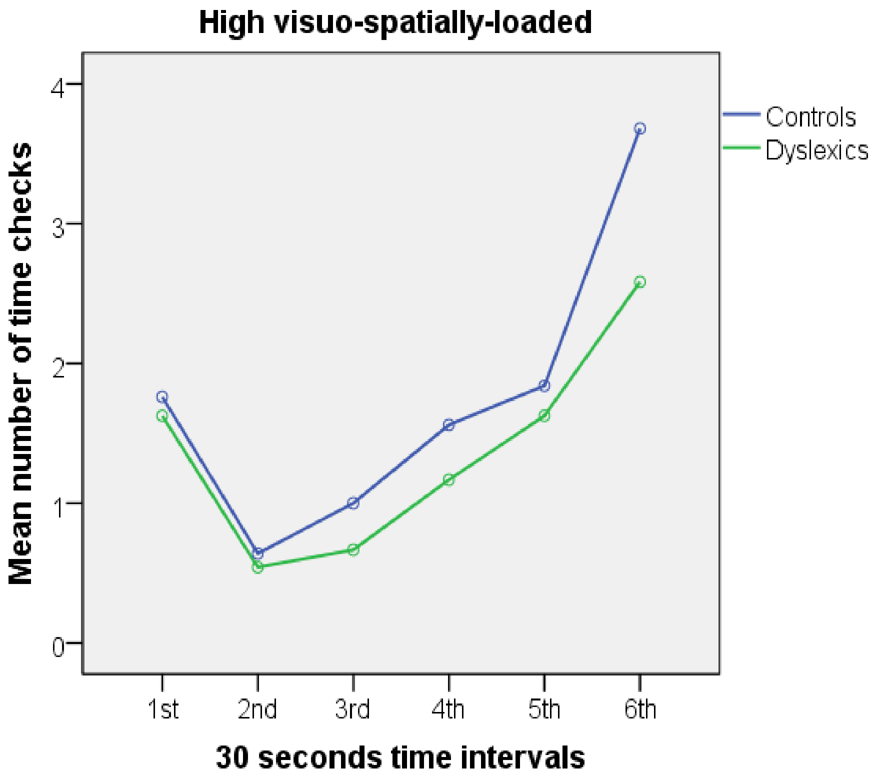


Figure 6: Time monitoring pattern of individuals with and without dyslexia in high visuo-spatially-loaded condition.



7.1.4. Discussion

The main significant finding from this analysis was that individuals with dyslexia were significantly less accurate on time-based PM tasks regardless of the cognitive/WM load as manipulated by the ongoing task modification. This supported the hypothesis that individuals with dyslexia have an overall deficit in time-based PM regardless of ongoing task load. There were no significant differences in accuracy between participant groups on the primary (all three conditions) and secondary (phonologically- and visuo-spatially-based) ongoing tasks. Even though there were no significant differences between the two participant groups in terms of time monitoring frequency and patterns, it should be noted that individuals with dyslexia performed fewer time checks compared to controls (effect of group approaching significance, $p = .060$).

Nevertheless, there was no interaction between participant group and cognitive load indicating that load did not significantly mediate group differences found in the PM accuracy data. The data also revealed that individuals with dyslexia had significantly slower RT in the primary ongoing task when compared to controls. There was also a significant interaction between participant group and load condition which indicated that load mediated the slower RT in individuals with dyslexia especially in the phonologically-loaded condition. This could be related to the phonological problem in dyslexia (e.g. Snowling, 1995). However, the general pattern of slower RT's was already found in the event-based experiments conducted in Studies 4 and 5 and is in line with the processing speed deficit argued by the double deficit hypothesis (e.g. Wolf & Bowers, 1999).

The PM deficit found in adults with dyslexia in the analysis of time-based PM involving the manipulation of cognitive load by changes to ongoing tasks is consistent with the findings from Studies 1 (PRMQ), 2 (PMQ) and 3 (MIST), indicating a time-based PM deficit in adults with dyslexia. In Study 1 individuals with dyslexia reported that their time-based PM failures occurred more frequently than controls, whereas in Study 2 they reported having significantly more internally cued PM failures. McDaniel and Einstein (2007) stated that time-based PM tasks conducted using laboratory paradigms are self-initiated. Thus, the time-based PM tasks employed within this current manipulation relied on internal cueing, with participants needing to initiate monitoring of the clock (time) in order to perform the intended activity. This process involves self-initiation of time-checking behaviour which in turn enables one to respond to the time-based PM task at the appropriate moment (d'Ydewalle et al., 2001). Furthermore, researchers (e.g. Harris & Wilkins, 1982; Einstein et al., 1995) found that smaller numbers of time checks generally result in worse PM performance in time-based PM tasks. Therefore, the results from the current time-based experiment could be explained on the basis of this reasoning, as participants with dyslexia generally spent less time monitoring the time compared to controls. This was the case across the three experimental conditions and their PM performance was significantly worse. Namely, it is possible that failure to self-initiate time-checking behaviour resulted in worse PM performance in dyslexics.

The argument that failure of self-initiation of time-checking behaviour leads to worse PM performance is also in line with the ageing literature which showed that older adults have been found to perform significantly fewer time checks (compared to younger adults) when performing time-based PM tasks (Einstein et al., 1995; Park et al., 1997), due to a problem with attentional resources. Moreover, McDaniel and Einstein (2007) suggested that it is the inability to monitor time that results in worse PM performance in older adults. Thus, the fewer time checks performed by individuals with dyslexia would seem to have a negative effect on their PM accuracy and this could be related to SAS deficits reported in dyslexia (e.g. Smith-Spark & Fisk, 2007), as the SAS has been argued to be responsible for allocation of attentional resources. Furthermore, self-initiated monitoring in the intention execution stage of time-based tasks has been shown to be controlled by prefrontal function/PFC (Burgess et al., 2001, Shallice & Burgess, 1991, Shimamura et al., 1991). Monitoring processes which are more heavily involved in time-based PM have been argued to rely strongly on SAS (Burgess and Shallice, 1997). Therefore, the finding indicating time-based PM deficits in dyslexia, acquired from the ongoing task load manipulation, is in line with the general dyslexia literature relative to attentional allocation and SAS/CE impairment (e.g. Jeffries & Everatt, 2004; Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007; Varvara et al., 2014).

Contrary to the evidence suggesting that the greater amount of time checks leads to a better time-based PM performance, Ceci and Bronfenbrenner (1985) argued that it is not the number of time checks itself that has this positive impact on the PM task performance, but their effective and strategic allocation. However, the results from current investigation did not support this argument as the time monitoring patterns of participants with dyslexia did not differ significantly compared to controls, but their PM responses were less accurate. Generally both participant groups monitored the time in a strategic way, with monitoring increasing towards the end of the three minute time intervals.

There were no significant group differences in the performance of the additional memory updating, ongoing tasks. It is possible that having to remember the last four items (as was the case in the memory updating tasks) was not sufficiently taxing to reduce dyslexic performance on these tasks or the primary ongoing tasks. The lack of significant differences in performance found in the updating tasks of the current study is different to the findings from a study conducted by Smith-Spark et al. (2003), who found that overall individuals with dyslexia performed significantly worse than controls on a letter updating task. Nevertheless, Smith-Spark et al. (2003) used an updating task which required participants to recall the last six consonants, and the number of consonants which needed to be recalled could be argued to be greater than the memory spans of some the participants. However, in the current study having to recall the last four items is most likely within the span abilities for all of the participants and thus could be argued to be not sufficiently taxing enough to result in performance differences.

The significant main effect of task type, after the inspection of means, indicated that regardless of participant group the additional phonologically-based task was less difficult compared to the visuo-spatial task. The lack of effect of participant group indicated that both groups performed similarly well on the memory updating tasks taken together and this finding also supports the reasoning that these tasks were not sufficiently taxing to reduce dyslexic performance on the ongoing task. In addition, the lack of significant interaction between participant group and tasks type indicated that the differences in the accuracies from the different types of tasks (i.e. phonologically-based or visuo-spatial) were not mediated by the factor of participant group. This is not in line with the phonological deficit hypothesis (Snowling, 1995) which suggested phonologically-based deficits in dyslexia as the results did not indicate that individuals with dyslexia had significant deficits in phonologically-based task compared to controls. Furthermore, this finding could be argued to support domain-general CE deficit in dyslexia suggested by Smith-Spark and Fisk (2007).

7.2. Naturalistic and semi-naturalistic measures of time-based prospective memory

This section of the chapter includes both a semi-naturalistic and a naturalistic task involving a time-based PM paradigm. Similarly to the event-based PM investigation, the rationale for carrying out these studies was to investigate how dyslexia-related PM problems might play out in more naturalistic settings and everyday life. The time-based naturalistic and semi-naturalistic tasks administered to participants in this investigation resembled the event-based semi-naturalistic and naturalistic tasks. Namely, the same time intervals as in the event-based tasks were used. The semi-naturalistic task involved a 40 minute interval between intention formation and intention execution, whereas the naturalistic task employed a one week time interval.

There have been a number of time-based PM investigations employing semi-naturalistic and naturalistic settings. For instance, Rendell and Thomson (1993) aimed to compare the time-based PM of young adults to that of older adults by employing a simulation of medication regimen. In their study eighty adult participants in five age groups were required to press a button on a small box at specified times over two weeks. Over a one week period participants had to press the button once every day at the same prescribed time and in another week the button needed to be pressed four times a day. The researchers recorded the number and times of the button presses. The results of this study showed that older adults were better at remembering to press the button on time then the younger participants. Even when the older participants were late, they were still closer to the prescribed times compared to younger adults. Researchers such as Kliegel, Martin, McDaniel and Phillips (2007) or Salthouse (1984) argued that older adults perform better than younger adults in everyday life-like tasks as they are able to compensate for their cognitive declines in attention or executive control processes (e.g. planning, switching and inhibition). It was argued that older adults learn how to deal with those life situations involving PM. Namely, it could be reasoned that older adults make a better use of memory aiding strategies.

Many of the naturalistic time-based PM studies such as the study conducted by Rendell and Thomson (1993) had one underlying limitation. Namely, because these studies often allowed participants to use memory aids or did not prohibit their use, the tasks used within these studies can be argued to be event-based PM tasks. Since participants were able to use external reminders such as clock alarms or calendar entries acting as PM cues reminding participants to perform the intended activities. The use of external reminders could also make the task easier and, moreover, it could even turn the PM task into a different kind of task, no longer involving PM at all. For example, if one uses an electronic reminder with an alarm sound and a description of what is required to be done at the specified time, such a task does not require one to hold an intention in memory as the electronic reminder could be said to hold the intention for the participant instead (comparable to external cognition; Scaife and Rogers, 1996). Thus, this would result in not having to remember prospectively, but rather rely solely on the reminder itself to remind participants about the intention to perform the action. Nevertheless, participants would still need to remember what they were intending to perform (the retrospective component) once they encountered the PM cue. In such a way individuals with PM problems (or more broadly with cognitive problems) could use this coping strategy to off load their memory load. Nevertheless, this would not allow the investigation of true PM abilities in naturalistic settings, but would rather explore the use of coping strategies such as memory aiding strategies. This is especially relevant to the current investigation as Study 2 showed that individuals with dyslexia reported that they relied significantly more on memory aiding strategies compared to controls.

There have been some studies which tried to address this issue. For example, Kvavilashvili and Fisher (2007) required participants to call the experimenter on the telephone at a particular time in six days and explicitly asked participants not to use memory aids. This time-based naturalistic PM study also compared the PM of young and older adults and found that older adults were better at prospective remembering in everyday settings. Another study which prohibited the use of memory aids was conducted by Rendell and Craik (2000). In this study participants had to recite the intended action into a recorder at certain times. This study also found that older adults outperformed younger adults. In addition in both of these studies (Kvavilashvili & Fisher, 2007 and Rendell & Craik, 2000) participants were asked whether they used memory aids to complete these tasks. Participants indicated in both of these studies that they did not use memory aids. However, this is based on self-reports which may be confounded by participant bias and the social desirability of responses.

Everyday tasks have been argued to differ strongly from laboratory based tasks in that they are more complex, open-ended and less structured (Altgassen, Koban & Kliegel, 2012). Everyday PM tasks often can be constituted by multiple sub-goals which need to be fulfilled in order for the final goal (the PM activity) to be achieved. Thus, one often needs to plan how to incorporate PM activities into ones daily schedule of all of the tasks that need to be performed. A plan is necessary in order to perform PM activities at the appropriate times regardless of whether one is occupied by other ongoing daily tasks. Bargh and Gollwitzer (1994) compared acting on implementation of intentions to acting out of habit and stated that both need a good plan for a successful completion.

The need for good planning abilities for successful PM completion points to a hypothesis that individuals with dyslexia will have a problem with their PM, since individuals with dyslexia have been found to have problems with planning (e.g. Gilroy & Miles, 1996; Levin, 1990; Weyandt, Rice, Linterman, Mitzlaff & Emert, 1998). Therefore, it could be predicted that individuals with dyslexia will have problems with everyday PM tasks which draw strongly on planning abilities. In addition, the literature related to EF and CE/SAS (discussed in Chapters 2 and 3) suggested a global problem in PM of individuals with dyslexia e.g. SAS/CE (Smith-

Spark & Fisk, 2007; Varvara et al., 2014), inhibition (e.g. Pallodino et al., 2001) and set shifting (e.g. Narhi et al., 1997). Since the executive control of attentional processes is required for directing the attention needed for successful PM task completion (Einstein et al., 2005). Namely, one needs to shift attention from the ongoing activity to the PM activity at the appropriate time. Thus, it was hypothesised that in both Study 9 and 10 participants with dyslexia will have significantly worse PM performance compared to age- and IQ-matched control participants.

7.2.1. Study 9: Semi-naturalistic task involving a delay of 40 minutes

This study was conducted under semi-naturalistic conditions, administered while participants were still in the laboratory. In this task participants were instructed to remind the experimenter to press the "B" button on the keyboard in order to save the data 40 minutes after the instruction. This task resembled closely the event-based tasks involving a delay of 40 minutes which required participants to remind the experimenter to press the "A" button when they saw the "The End" screen in order to save the data from the experiment. The use of semi-naturalistic design ensured that the participants did not use external memory aids to help them with remembering to perform the intended action. However, the use of this type of setting limited the length of time interval between the intention formation and intention execution to a duration acceptable to participants for a lab-based study.

7.2.1.1. Method

7.2.1.1.1. Participants

The same participants as in Study 8 were employed for this task. Please see the Participants section of Study 8 for information about the participants and section 4.1.2.1.1. of Study 1 for group matching procedure.

7.2.1.1.2. Materials

A data collection grid was used to enable the researcher to record the time and content of responses.

7.2.1.1.3. Design

This task was performed during the first testing session. This study employed a scoring system similar to that of the MIST (Raskin, 2004). Thus, a score of zero was given to participants who forgot to remind the experimenter to press the “B” button within five minutes of the designated time (+/- 5 minutes). A score of one was given to participants who remembered that they had to remind the experimenter about something but could not recall the content of this action i.e. to press the “B” button. A score of two was given to participants who remembered to remind the experimenter to press the “B” button in order to save the data within five minutes of the designated time.

A 2 x 3 Chi-square design was employed to analyse the data. The predictor variable in this study was the participant group (dyslexic vs. controls) and the criterion variable was the response to the semi-naturalistic PM task (no response, content lost and correct response).

7.2.1.1.4. Procedure

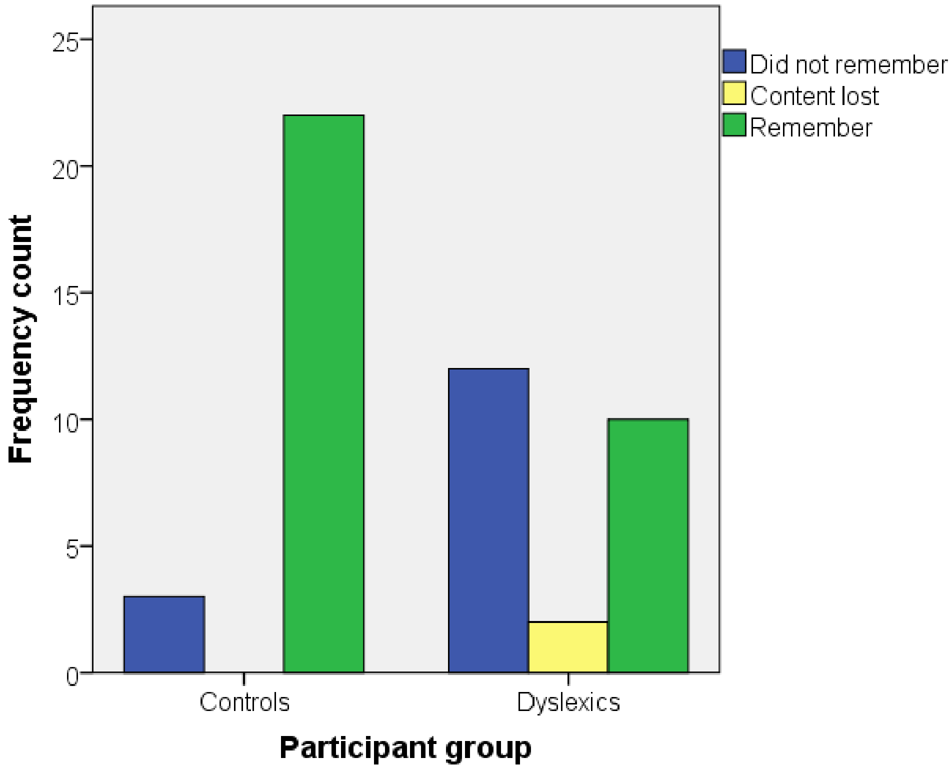
Informed consent was acquired from all participants prior to testing. In this study participants were instructed verbally at the beginning of the experimental session to remind the experimenter to press the “B” button on a keypad in 40 minutes in order to save the data. After this instruction participants were engaged in other tasks. Namely, participants performed two of the three experimental conditions which were presented in a counterbalanced order. A naturally occurring break between these tasks occurred approximately after the 35th minute from the start of the study. The experimenter monitored the time in order to enable all participants to see the clock on the desktop computer in front of them if they wished to check it in order to perform the semi-naturalistic PM task. In order to achieve this the experimenter waited approximately until the 45th minute from the start of the experiment in order to allow participants to remind the experimenter to save the data 40 minutes from the start (+/- 5 minutes). During this break the experimenter asked participants what they thought of the last task and to prepare for the next task. Participants were debriefed at the end of the study.

7.2.1.2. Results

There were three participants with dyslexia who performed the PM task outside of the 10 minutes time window (+/- 5 minutes from the designated time) and thus were given a score of zero.

The results from Pearson Chi-square revealed that there was a significant association between participant group and response to the time-based semi-naturalistic PM task, $X^2 = 11.89$, df = 2, $p = .003$. Adults with dyslexia were more likely to not remember about the PM activity, than to remember it, whilst individuals without dyslexia were more likely to remember about the PM task and less likely not to remember. Figure 7 represents frequency counts for the two participant groups.

Figure 7: The association between participant group and performance on the time-based semi-naturalistic PM task.



7.2.1.3. Discussion

The results from this study showed that individuals with dyslexia were more likely to forget to perform the PM task after 40 minutes compared to age- and IQ-matched controls. The findings from this everyday semi-naturalistic task supported the hypothesis that individuals with dyslexia have a PM deficit in comparison to controls. One possible explanation of these results could be related to problems with planning in dyslexia (e.g. Weyandt et al., 1998). Everyday PM tasks have been argued to require good plans to be made for the completion of all of the multiple sub-goals leading into successful PM performance (Altgassen et al., 2012). In addition, Altgassen and colleagues stated that planning is necessary in order to be able to perform the PM activity at the correct time whilst maintaining all the other daily ongoing tasks. Thus, there is a possibility that the results of this study indicated that a problem with planning abilities could underlie the everyday PM failure found in individuals with dyslexia. Nevertheless, this was not investigated directly in the current thesis and could be proposed for a future study idea.

The results of this study are also in line with the literature showing problems in dyslexia related to EF and allocation of attention e.g. shifting (Hari & Renvall, 2001), SAS (Varvara et al., 2014) and CE (Smith-Spark & Fisk, 2007; see Chapter 2 for more details). Since individuals with dyslexia were engaged in an everyday ongoing activity while they had to switch to the performance of the PM task. Thus, if individuals with dyslexia have problems with switching attention to the performance of the PM task at the appropriate time, this could be argued to be due to problems with attentional processes overseen by the CE component of WM and is based on executive resources.

7.2.2. Study 10: Naturalistic task involving a one week delay

This time-based investigation was carried out under naturalistic settings which permitted the use of a longer time interval between intention formation and its execution. In this study participants were asked to send a text message with their name at a prescribed time one week after the instruction. This task was designed in order to match the event-based naturalistic task where participants had to respond to a text message sent to them one week after leaving the laboratory. Participants were requested to not use any external reminders such as calendar entries or sticky notes. However, it was impossible to ensure that participants did not use external memory aids even though they were instructed not to do so. This procedure was in line with other researchers who also asked participants to not use any external reminders (e.g. Kvavilashvili & Fisher, 2007; Rendell & Craik, 2000). The longer time intervals used within this study are more likely to result in lower PM performance compared to shorter time intervals due to memory decay processes. It was hypothesised that individuals with dyslexia would be significantly less able to remember to perform the time-based PM task involving one week interval compared to age- and IQ-matched controls.

7.2.2.1. Method

7.2.2.1.1. Participants

There were two groups of participants, adults with developmental dyslexia and controls matched for age and IQ. Please see participants section of Study 8 for information about the participants.

7.2.2.1.2. Materials

Instruction sheets with an explanation of what was required in this naturalistic study as well as questions about mobile phone usage were used (see Appendix 10). A mobile phone with a new SIM card was used by the researcher for the purpose of this study. This mobile phone number was not used for any other purposes.

7.2.2.1.3. Design

This study was attached to the second testing session. Similarly to that used in Studies 3 and 9, this study employed a scoring system. A score of two was given to participants who remembered to send the text message to the experimenter one week after the instruction was given. A score of one was given to participants who remembered to send the text message one week from the instruction but the text message did not contain the participant's name and surname. A score of zero was given to participants who forgot to send the text message one week after the instruction (+/- 2 hours).

A 2 x 3 Chi-square design was employed to analyse the data. The predictor variable in this study was the participant group (dyslexic vs. controls) and the criterion variable was the response to the naturalistic PM task (no response, content lost and correct response).

7.2.2.1.4. Procedure

Informed consent was acquired from all participants prior to testing. Participants were instructed to send a text message (SMS) one week after the instruction was provided. This instruction was given after participants had completed the second testing session. Participants were explicitly shown the date, the day of the week and time at which they were required to text on the information sheet. Each participant was asked to include their name and surname in the text message. Participants were asked not to use any external reminders such as calendar entries, reminders or sticky notes. This instruction was given in order for the participant to rely purely on PM rather than on external reminders. Participants were also not allowed to write down the experimenter's telephone number on a piece of paper as this could act as a reminder (a PM cue). Instead participants were asked to save the experimenter's number directly into their mobile phone contacts.

After the instructions were provided all participants reported that they understood what was required of them in this study and explained the instructions to the experimenter. Participants were also asked whether their phones were pay monthly or pay-as-you-go phones in order to rule out all participants who may not have been able to send the text message because of insufficient funds on their mobile phone accounts. If a participant stated that he or she had a phone on a pay-as-you-go tariff, he or she was asked whether there were long periods of time when they had no money on their own account to send a text message. These questions ensured that all of the participants were able to send the text message when they were required to do so. Additional questions were asked with regards to competency in using mobile phone for sending text messages. All of the participants reported that they were competent in doing this. Participants were debriefed at the end of the study.

7.2.2.2. Results

Twelve participants (seven with dyslexia and five without) who took longer than two hours to respond to the text message were considered as having forgotten about the PM task (and scored 0).

The results from Pearson Chi-square revealed that there was no significant association between participant group and response to the one week PM task, $X^2 = 2.67$, df = 2, $p = .263$. Adults with dyslexia did not differ significantly in their ability to remember and perform the PM activity compared to controls. Table 31 shows the frequency counts for the two participant groups.

Table 31: Frequency counts representing frequency counts for the two participant groups.

	Participant group	
	Controls	Dyslexics
Did not remember	21	20
Content lost	2	0
Remembered	2	4

7.2.2.3. Discussion

The results of this study showed no significant differences between participants with dyslexia and age- and IQ-matched controls under everyday life naturalistic conditions involving one week time delay. Thus, these results did not support the hypothesis that time-based PM deficits occur in dyslexia over longer time intervals. It could be argued that these results were not in line with the literature suggesting problems with attentional control in individuals with dyslexia as no PM group differences were found. However, it is possible that the one week time interval used in this study was too long for all participants making it very difficult to remember the PM activity without the use of external memory aids. Indeed, the results showed that both of the participants groups performed at close to floor in this task. Thus, it is possible that because this task was too difficult for both groups of participants there was no group difference observed. Nevertheless, the frequency counts of the two participant groups showed marginally better PM in adults with dyslexia compared to controls. This marginal difference could indicate that participants with dyslexia were slightly better or more motivated than controls on this task. This possible slight advantage in PM of dyslexic individuals is in line with the ageing literature (e.g. Kliegel, Martin, McDaniel & Phillips, 2007; Salthouse, 1984) which argues that older adults performed better than younger adults in everyday life-like tasks as they were be able to compensate for their cognitive declines in attention or executive control processes (e.g.

planning, switching and inhibition). It was argued that older adults learned how to deal with those life situations involving PM. A similar argument might be made for people with dyslexia, based on the results.

It is worth mentioning that in both time-based designs (semi-naturalistic and naturalistic) it was not certain whether participants used memory rehearsal as a memory aiding strategy acting as a coping strategy. It is possible that individuals with dyslexia engaged more in this type of strategy in order to cope with the task, despite being instructed not to. If this study was to be conducted again, participants should be asked if they used any type of memory aiding strategies (especially memory rehearsal) after completion of the task.

Another explanation of the results from this naturalistic investigation could be suggested in relation to perceived task difficulty. Namely, it is possible that individuals with dyslexia, aware of their attentional problems, placed more importance on this task as they saw it as being more difficult. This is in line with the attentional allocation view suggested by Marsh, Cook and Hicks (2006) where participants allocate more importance to more difficult tasks. It is also possible that participants with dyslexia were more engaged in this study as it was about "them", i.e. people with dyslexia. In addition, one could argue that the naturalistic PM task had a stronger emphasis placed on it compared to the semi-naturalistic task. Since the semi-naturalistic task (Study 9) involved only a short verbal instruction compared to the naturalistic task (Study 10) which involved longer written instructions incorporating questions regarding mobile phone usage. This difference in the amount of time and attention placed on both of these tasks could have resulted in more importance being placed on the naturalistic task. It is also possible that this imbalance resulted in more memory rehearsal processes being performed by individuals with dyslexia in the naturalistic task. Individuals with dyslexia have reported using more memory aiding techniques in Study 2. Therefore, it is possible that because there was a larger emphasis placed on the naturalistic task and because participants with dyslexia saw it as more difficult, this resulted in more rehearsal strategies used by dyslexic individuals and in turn produced performance similar to controls.

The difficulty with naturalistic designs such as the one used in the current study is that it is unknown whether participants were engaged in any other ongoing activities and whether these were affected in any way. Thus, it could be suggested that in future investigations participants should be followed up soon after the time to perform the PM task passes in order to find out whether they were engaged in any other secondary activities, how demanding these activities were and whether having to remember this PM task had caused them any difficulties with the other scheduled daily tasks. Nevertheless, since the performance was low for all participants it may be also suggested that a shorter time interval between intention formation and its execution should be used if the study was to be carried out again.

7.3. Summary

The findings of this manipulation of load through additional ongoing tasks suggested a time-based PM deficit in adults with developmental dyslexia. It was suggested that EF and SAS/CE problems in dyslexia could underpin the time-based PM deficit found in dyslexia. The amount of time monitoring was suggested to play some role in PM performance. Namely, a smaller number of time checks could be indicative of less cognitive resources available to perform PM tasks which in turn could be related to worse PM performance. The results from the cognitively demanding memory updating tasks did not show significant differences between dyslexics and controls regardless of the processing type that they involved (phonological or visuo-spatial). It was argued that this could be related to PM deficits. Namely, participants were engaged with these engaging ongoing tasks which resulted in comparable to normal performance found in these tasks. However, this could have resulted in worse PM performance due to the inability to inhibit responding to the ongoing trials and switch to the PM/time monitoring tasks. Individuals with dyslexia were also found to have generally slower RT of responses compared to controls which was argued to be in line with the processing speed deficit in dyslexia proposed by the double deficit hypothesis (e.g. Wolf & Bowers, 1999).

The semi-naturalistic time-based PM task involving a delay of 40 minutes, showed that individuals with dyslexia have a PM deficit which was in line with the time-based PM problems suggested on the basis of the results from PMQ, MIST and the experimental work. However, this was not observed in the naturalistic time-based PM task involving a one week time delay. The lack of a PM deficit in this one week delayed task was argued to have occurred due to floor performance on this task by both participant samples. These results were argued to indicate that there is a greater problem in time-based PM in adults with dyslexia compared to event-based PM.

Chapter 8: Implications for theory including direction for future research, practical recommendations and a conclusion

8.1. Summary of main findings

Overall this thesis revealed that adults with developmental dyslexia have a deficit in PM. In looking at self-reports (see Chapter 4) individuals with dyslexia perceived themselves as having a problem with time- and event-based everyday PM activities (evidence from responses to PRMQ; Smith et al., 2000). These data were corroborated by ratings taken from close friends/relatives of the participants. The findings from the PMQ (Hannon et al., 1995) also supported the time-based PM deficit in dyslexia, found using the PRMQ and PRMQ-for-others. Compared to controls individuals with dyslexia reported having more difficulties with PM tasks involving long-term intervals where the PM activity occurs rarely. On the contrary, individuals with dyslexia did not self-report deficits in PM tasks involving short-term time intervals and occurring habitually. Participants with dyslexia also reported using techniques that assisted memory (e.g. reminders, rehearsal and planning) significantly more frequently compared to controls.

The event-based PM in semi-naturalistic conditions involving a time interval of 40 minutes did not support the results from self-reported data (PRMQ and PRMQ-for-others), as there was no significant group difference. However, the naturalistic event-based PM task involving considerably longer time interval of one week was in line with the self-reported PM impairment in dyslexia, revealing significant group differences in day-to-day life settings. The results from the experimental work involving event-based PM (Studies 4 and 5) revealed no deficits in dyslexia. The findings from the experimental work do not support event-based PM deficits in individuals with dyslexia. However, it is possible that the ongoing task used in the focal and non-focal designs may not have been cognitively demanding enough to reveal a PM deficit in individuals with dyslexia. Nevertheless, the naturalistic evidence suggests that there may be a dyslexia related problem with event-based tasks involving considerably longer time intervals. As this is a new area of research and the finding is based on only one task, replication of this study would provide more robust evidence.

The results from the semi-naturalistic study involving time-based PM task with a delay of 40 minutes, showed a PM deficit in adults with dyslexia confirming the findings from self-reports (PRMQ, PRMQ-for-others and PMQ). Further support for time-based PM deficits in dyslexia comes from the naturalistic time-based PM task which involved a longer time delay of 24 hours under every-day life conditions. Moreover, this finding is in line with the results from the naturalistic even-based PM task involving considerably longer time-intervals (24 hours and one week in comparison to 20 and 40 minutes). This may indicate that individuals with dyslexia may have PM deficits in tasks involving a longer time-intervals regardless of the type of PM (time- or event-based). However, there were no group differences in performance on the one week time-based task, but a floor effect was observed in this study which made the results inconclusive and further research is needed. The experimental work involving time-based PM supported the findings from the self-reports and every-day life measures showing a time-based PM problem in dyslexia. It was found that individuals with dyslexia were significantly less able to remember to perform the time-based PM tasks during the laboratory based design. There was no effect of load found in the manipulation of ongoing task load and no interaction between participant group and cognitive load. Overall, the findings indicate time-based deficits in individuals with dyslexia compared to controls, regardless of the length of time-interval.

The results of the clinical measure of PM (the MIST; Raskin, 2004) also supported the pattern of time-based PM deficit in dyslexia involving short-time intervals (MIST involved 2 and 15 minute short-time intervals only). The results from MIST memory load analysis suggested that high cognitive load negatively affected both the dyslexic and control groups. However, there was there was no interaction between memory load and participant group. The lack of interaction between participant group and memory load supports the results from time-based PM experiment manipulating the load of ongoing task, as it also found no interaction between participant group and load.

In summary, the general pattern suggests more problems with time-based PM in dyslexia compared to event-based PM. This pattern was supported by the results from Studies 2 (PMQ), 3 (MIST including the naturalistic measure), 8 (time-based experiment) and 9 (semi-naturalistic time-based design). Furthermore, experimental designs investigating event-based PM (Studies 4 and 5) did not indicate event-based PM deficits in dyslexia. There was only one study which indicated an event-based PM problem in dyslexia and this was the naturalistic study involving one week time delay (Study 7). Therefore, there appears to be more robust evidence to suggest time-based PM deficits in dyslexia. The results also suggest dyslexia related deficit in event- and time-based PM tasks involving considerably longer time-intervals (24 hours time-based and one week event-based tasks) whereas in tasks involving shorter time-intervals (3, 20 & 40 minute) individuals with dyslexia only showed deficits in time-based PM tasks.

8.2. Implications for theory

The results from this thesis provided an original contribution to the literature. The dyslexia deficit found in PM has a number of theoretical implications. Firstly and most importantly, individuals with dyslexia have been found to have problems with PM. Researchers have shown that there are short-term memory/WM problems in dyslexia (e.g. Olson and Datta, 2002; Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007; Varvara et al., 2014), but there has been no research up to date, which has demonstrated PM problems in dyslexia.

Secondly, the findings from this thesis suggested that deficits in dyslexia are not limited to phonological skills as it has been argued previously by the phonological core deficit hypothesis of dyslexia (e.g. Frith, 1985; Ramus, 2003; Snowling, 2000; Stanovich, 1988; Vellutino, 1979; Vellutino et al., 2004). Furthermore, the findings from this thesis have also shown that deficits in dyslexia are not limited to childhood, but that these carry on into adulthood. There are also other implications for theory arising from the results acquired in this thesis (e.g. implications for event-based PM theory) and these are discussed in this chapter.

8.2.1. Implications for event-based prospective memory

8.2.1.1. Spontaneous retrieval vs. monitoring theories

The spontaneous retrieval theory (Einstein & McDaniel, 1996; Guynn et al., 2001; McDaniel & Einstein, 2000; McDaniel et al., 2004) argued that in event-based tasks the PM cue acting as a reminder about the PM activity, can trigger the PM response automatically and thus it was claimed that monitoring is not needed in event-based PM tasks. On the contrary monitoring theories (i.e. PAM theory; Smith, 2003; Smith & Bayen, 2004) argued that event-based PM tasks continuously engage non-automatic monitoring processes. The PAM theory (Smith, 2003) argued that monitoring is involved in all event-based PM tasks on the basis of cost visible on ongoing trials of a PM paradigm. The results from the two event-based PM experiments conducted as a part of this thesis could be argued to support the claims of PAM (Smith, 2003) theory and more generally monitoring theories, as both of the tasks found cost to the ongoing tasks in the experimental blocks involving PM trials. In accordance with PAM theory, it could be argued that the retrieval of PM intention in event-based PM tasks is a non-automatic process and it employs preparatory attentional processes (monitoring) for successful completion. Thus, the spontaneous retrieval theory of event-based PM (e.g. Einstein & McDaniel, 1996) was not supported by the results from this thesis.

8.2.1.2. Multiprocess theory

The multiprocess theory proposed that the focality of the PM cue determines the degree to which monitoring is needed for PM retrieval (Scullin et al., 2010). This theory argued that non-focal PM tasks are more likely to require monitoring processes compared to focal tasks. As a result of this, it has been reasoned that non-focal tasks are more likely to result in a cost to the ongoing tasks compared to focal tasks (e.g. Einstein et al., 2005). Thus, it could be argued that the RT data from the focal and non-focal PM experiments conducted in this thesis supported the multiprocess view in that no significant effect of cost was found in the focal design and a significant main effect of cost was found in the non-focal design. These results are in line with other studies (e.g. Einstein et al., 2005; Scullin et al., 2010) which found significant task interference (cost to the ongoing task) in the non-focal conditions and its absence in focal conditions. Therefore, it could be argued that the focal design used within this thesis involved fewer monitoring processes and thus relied more on automatic processes in comparison to the non-focal design. However, it should be noted that the effect of block type in the focal design was approaching significance ($p = .054$) and there was a main effect of block type in the non-focal design ($p = .002$). Therefore, it could be reasoned that both the focal and non-focal designs used in this thesis showed a cost to the ongoing tasks which was related to the performance of the PM tasks. This on the other hand could be argued to support the PAM theory (Smith, 2003) in that all event-based PM tasks involve preparatory attentional monitoring processes, which require cognitive resources. Thus one may argue that the multiprocess theory was not supported by the results from the event-based PM experiments conducted as a part of this thesis. Namely, that both types of event-based PM (focal and non-focal) rely on monitoring processes. This later statement seems to be a more plausible implication for event-based PM theory, but the levels of monitoring employed in both types of tasks may vary. Namely, the significant main effect found in the non-focal design and the approaching significance effect in the focal design could reflect the reasoning that non-focal designs rely more on monitoring processes and thus result in greater cost to the ongoing trials compared to focal designs. However, this is not to say that one type involves monitoring and the other does not as suggested by the multiprocess theory.

Nevertheless, a potential confounding problem reported in the general discussion of the event-based chapter (section 6.1.3.) could suggest that there was a possibility for the need for monitoring in the focal design used in this thesis. Namely, one could argue that one of the PM cues (glasses) employed in the focal design was less salient compared to the other PM cues employed in the focal and non-focal designs, which could have resulted in the need for monitoring also in the focal design. According to multiprocess theory of PM (McDaniel & Einstein, 2000), salient PM cues are more likely to result in automatic retrieval of the PM intention compared to less salient PM cues which were argued to rely more on monitoring processes. Thus, it is possible that the less salient PM cue employed in the focal design required monitoring processes to be employed for successful retrieval of PM intention and thus it is difficult to form firm conclusions on the basis of these results. However, this comparison of the PM cues is highly speculative and thus further investigation of cue saliency in relation to dyslexia is recommended.

8.2.1.2.1. The dynamic multiprocess framework

On the contrary to the afore mentioned lack of support for the multiprocess theory showed by the event-based PM experiments employed in this thesis, this work could be argued to support the dynamic multiprocess framework proposed by Scullin et al. (2013). This framework proposed that if participants are explicitly instructed to expect PM cues, they will selectively engage in monitoring processes in event-based PM tasks. This could be argued to explain why there was cost to the ongoing trials in the experimental blocks of focal and non-focal PM tasks which included PM trials. Namely, it could be reasoned that participants chose to engage in monitoring processes in the experimental blocks as they were instructed that these blocks will include PM cues. On the other hand, it would also explain the shorter RTs in the baseline blocks (in comparison to the experimental blocks) which involved no PM cues as participant were not informed to expect PM cues and did not monitor for PM cues as a result of this. Thus, the dynamic multiprocess framework was supported by the findings from the event-based PM experiments conducted as a part of this thesis.

8.2.2. Implications for time-based prospective memory

8.2.2.1. Self-initiated monitoring in time-based prospective memory

Researchers (e.g. d'Ydewalle et al., 2001; Einstein & McDaniel, 1990; Groot et al., 2002) have suggested that time-based PM tasks generally involve more self-initiated monitoring and are more difficult compared to event-based PM tasks. McFarland and Glisky (2009) have suggested that time-based PM tasks may require more self-initiated monitoring processes as one needs to monitor time in the absence of external cues which can act as a trigger for the retrieval of the PM intention. It could be advocated that the dyslexia-related PM deficit found in the time-based PM experiment and the lack of the deficit found in event-based PM tasks supported the claim that time-based PM tasks are more difficult and involve more self-initiated monitoring compared to event-based PM tasks. This statement could be made on the basis of the literature proposing dyslexia related performance deficits in complex tasks (e.g. Nicolson & Fawcett, 1990; Smith-Spark & Fisk, 2007). Thus, one could argue that time-based PM deficits found in dyslexia on the basis of the experimental work occurred as these tasks were complex enough to prevent individuals with dyslexia from utilising conscious compensation (CC) processes which normally mask their tasks performance deficits. On the other hand, it could be argued that the event-based PM tasks were not complex enough to prevent CC in dyslexia and thus resulted in comparable to controls PM performance. This may be related to a greater difficulty of time-based over event-based tasks as time-based tasks were argued to involve more self-initiation of the monitoring processes (e.g. Einstein & McDaniel, 1990; Groot et al., 2002). Time-based PM tasks may be more capacity consuming then event-based PM tasks due to the involvement of self-initiation of the monitoring processes and thus may leave fewer resources for conscious compensation processes in dyslexia. Thus, it could be concluded that the results supported the claims that time-based PM tasks are more difficult and involve more self-initiated monitoring compared to event-based PM tasks. Furthermore, self-initiated monitoring has been argued to be controlled by prefrontal functioning (McFarland & Glisky, 2009) and individuals with dyslexia have been found to have deficits in frontal functioning (Swanson, 2006).

Similarly the semi-naturalistic work supports the literature suggesting that time-based PM tasks are more difficult as they involve more self-initiation when compared to event-based tasks (e.g. d'Ydewalle et al., 2001). Namely, the results from the semi-naturalistic studies involving 40 minute delays showed a dyslexia-related PM deficit in time-based PM but not in event-based PM. This may be because participants needed to rely more strongly on self-initiation in the time-based PM task as it did not include any external cues to aid PM retrieval whereas, the event-based task involved a PM cue which acted as a reminder of the intended activity. Thus, the event-based tasks did not involve self-initiation of the PM intention. This reasoning is in line with Craik's (1986) framework of memory which stated that memory tasks can be ordered by the extent to which they require self-initiated processes in memory retrieval. In the time-based PM task participants needed to actively search for the clock in order to check if it was the right time to perform the PM activity. However, in the event-based task "the end" screen was easily visible as participants had their heads in a chin-rest (locked in position) with "the end" screen directly in their line of vision. Therefore, participants did not need to search for the event-based cue. In the time-based task the only clock available to participants was a clock in the right bottom corner of a desktop computer windows screen (as it usually appears in any Windows desktop). This clock was less visible and distinct than the event-based PM cue. Thus, in line with the literature (e.g. Einstein et al, 1995), it could be argued that the time-based semi-naturalistic task relied on self-initiated processes whereas the event-based task on spontaneous retrieval processes. This could explain the deficits found in the dyslexic group on the time-based semi-naturalistic task (but not on the event-based task), as self-initiation requires cognitive resources and thus is more demanding than spontaneous memory retrieval. Further investigation is required to fully test this explanation.

8.2.2.2. Executive functioning involvement in time-based prospective memory tasks

Gonneaud et al. (2011) argued for a strong reliance of time-based PM tasks on inhibition. The current results from time-based PM tasks could be argued to support this claim, as individuals with dyslexia who were reported to have inhibition deficits (e.g. Swanson, 2006) were found to have a time-based PM deficit. In addition, SAS has been also claimed to be responsible for inhibition processes (e.g. Norman & Shallice, 1986) and individuals with dyslexia have been claimed to have SAS deficits (e.g. Smith-Spark & Fisk, 2007). This adds further to the argument that time-based PM tasks rely strongly on inhibition as only time-based PM paradigm resulted in dyslexia related PM deficit. The SAS has been proposed to be a candidate for the CE component of WM (Baddeley, 1986). Basso et al. (2010) showed that ongoing tasks involving higher WM impacted negatively on time-based PM performance. The deficit in time-based PM found in dyslexia could be suggested to support the involvement of WM in time-based PM. Basso and colleagues also stated that WM resources are shared with time-based PM resources in tasks involving high demands. Individuals with dyslexia have been reported to have WM deficits and insufficient cognitive resources in complex tasks (e.g. Nicolson & Fawcett, 1990; Smith-Spark, 2007) and thus, it could be proposed that the shortage of WM resources shared with time-based PM resources resulted in time-based PM deficits in dyslexia. This could be suggested to support the involvement of WM processes in PM, especially in the more complex time-based PM paradigms.

8.2.3. Implications for dyslexia

8.2.3.1. Attention in dyslexia

Individuals with dyslexia have been argued to have problems with attentional resources (e.g. Fawcett & Nicolson, 1992; Smith-Spark & Fisk, 2007). The time-based PM deficit and the lack of the event-based PM deficit found in dyslexia could be argued to support this claim. The monitoring processes, reasoned to draw on attentional resources, were argued to make time-based PM tasks more difficult compared to event-based tasks and result in worse PM performance (e.g. Einstein et al., 1995) and greater age-related PM deficits (e.g. Craik & Byrd, 1982). Thus, it could be argued that the deficit found in dyslexia in time-based but not in event-based tasks could be indicative of the greater involvement of attentional resources in time-based PM, considering that individuals with dyslexia have problems with attentional resources. It is possible that this is due to the strong requirement in time-based PM tasks to self-initiate the monitoring of the time in order to perform successfully the time-based PM task, whereas in event-based PM tasks the PM intention can be triggered by the PM cue. Furthermore, in line with this argument that the dyslexia deficit found in time-based PM tasks supports the problems with attentional resources in dyslexia is the finding suggesting a failure to self-initiate time-checking behaviour by individuals with dyslexia as found by the smaller number of time checks in the time-based PM experiment. Namely, it is possible that the smaller number of time checks in dyslexia compared to controls occurred due to the lack of sufficient attentional resources to check the time with sufficient frequency to succeed at the time-based PM task. This is in line with the reasoning presented in the aging literature (e.g. Park et al., 1997) which argued that fewer time checks in older adults results in worse time-based PM performance due to insufficient attentional resources.

It is also possible that the results from the time-based PM experiment, which found a PM deficit in dyslexia, support the claim that individuals with dyslexia have distractible attention (e.g. Nicolson & Fawcett, 1990; Smith-Spark et al., 2004). That is to say, the attention of participants with dyslexia could have been distracted by the ongoing tasks which could have resulted in worse PM performance and fewer time checks than controls. Thus, it could be reasoned that the attention directed towards the intention to perform the PM activity at a particular time was distracted by the absorbing and cognitively demanding ongoing tasks, drawing the participant's attention and taking it away from the PM intention.

It is also possible that individuals with dyslexia could find themselves side-tracked with absorbing activities in their everyday life conditions (e.g. Augur, 1985) which would have taken their attention away from self-initiated time monitoring processes required for the PM activity and subsequently from performing the time-based PM tasks. Smith-Spark et al. (2004) found that individuals with dyslexia reported themselves to be more distractible and over-focusing than controls, which results in relevant peripheral information being missed. The eye-tracker data acquired from the event-based experiments conducted as a part of this thesis supported this argument, finding that individuals with dyslexia may be over focusing as more eye-fixations were found. In addition, it was found that controls were less likely to fixate on the PM cues whilst still performing the PM tasks correctly in comparison to the dyslexic group who appeared to have to allocate more attention on focusing on the PM cues in order to perform the PM task successfully. Whilst this could be a sign of over focusing, further investigation is needed to establish this. Significant others of individuals with dyslexia in the study conducted by Smith-Spark et al. (2004) rated individuals with dyslexia to be more absentminded compared to controls. These claims may support the argument that individuals with dyslexia could get side-tracked and absorbed with activities resulting in PM deficits in everyday life conditions, especially in tasks involving longer time intervals. Nevertheless, memory decay processes are more likely to take place in tasks involving considerably longer time intervals (Tobias, 2009).

8.2.3.2. Executive functions in dyslexia

It is also possible that the problems found in dyslexia related to insufficient amount of time checks and the deficits in time-based PM are related to problems with SAS reported in dyslexia (e.g. Smith-Spark & Fisk, 2007). It is therefore possible that the deficit found could indicate that individuals with dyslexia have problems with allocation of attentional resources to monitor the time and subsequently perform the time-based PM tasks. The SAS argued to be related to EF (Hayes et al., 1996) is responsible for allocation of attentional resources (Norman & Shallice, 1986) and thus it is conceivable that the time-based PM deficits found in dyslexia support the deficit in SAS in dyslexia. This argument is also in line with Cockburn (1995) who argued that environmentally cued PM tasks (i.e. event-based) require less attentional control than time-based PM tasks. Since event-based PM tasks can elicit responses when the PM cue is recognised and without the need to search for the PM cue. Therefore, if time-based PM tasks, which resulted in deficits in dyslexia, require more attentional control and individuals with dyslexia have been reported to have problems with SAS which mediates attentional control, it could be reasoned that this finding supports problems with SAS in dyslexia.

The SAS has been also argued to be responsible for inhibition of values of behavioural schemas (Norman & Shallice, 1986). Gonneaud et al. (2011) in their study investigating the relationships between event- and time-based PM measures and a wide range of cognitive functions (related to frontal lobe functioning) highlighted the strong reliance of time-based PM tasks on inhibition. Furthermore, McFarland and Glisky (2009) argued that time monitoring involves the continual interruption of ongoing activities. Individuals with dyslexia have been reported to have problems with inhibition (e.g. Palladino et al., 2001; Varvara et al., 2014) and thus it is possible that the time-based PM deficits found in this thesis are underpinned by deficits in inhibition. It could be reasoned that individuals with dyslexia found it difficult to inhibit responses to the ongoing tasks in order to switch to the PM activity. Indeed, individuals with dyslexia have been also reported to have difficulties with task switching ("sluggish attentional shifting" - Hari & Renvall, 2001; Narhi et al., 1997) in addition to inhibition problems. Time-based tasks require participants to direct attention away from the ongoing task in order to monitor the time or to perform the PM task. This process involves shifting of attentional resources and it could be argued to be maintained by executive attentional system such as the Norman and Shallice's (1986; Shallice, 1988) SAS, as it is responsible for directing attentional resources. Literature suggests that individuals with dyslexia have SAS deficits (e.g. Fawcett & Nicolson, 1992; Smith-Spark & Fisk, 2007) and the finding showing a time-based PM deficits on the laboratory based task could be argued to support this deficit. Therefore, the time-based PM deficit found in dyslexia could be argued to support problems with inhibition and shifting abilities in dyslexia reported in the literature (e.g. Palladino et al., 2001; Hari & Renvall, 2001).

Cockburn (1995) argued that some time-based PM tasks may require interruption of the ongoing task whilst others may complement the ongoing task. Cockburn undertook a case study on J.B., who had frontal lobe damage which resulted in impairments in planning, initiation and inhibition of ongoing behaviour. Cockburn found that J.B. was able to perform PM tasks involving inhibition that were compatible with continuation of the ongoing activity (e.g. interrupting the ongoing tasks to change pens). Her PM difficulties were argued to be related to PM tasks not compatible with the continuation of ongoing activity (see Chapter 1 for more details). It was explained that this was related to the strength of activation of target context which needed to override the level of activation generated by the ongoing tasks, in order for J.B. to break out from the ongoing activity (in tasks which required self-initiated interruption). In line with Cockburn's findings, time-based PM tasks which involve interruption of an ongoing activity, where the PM task is not compatible with continuation of the ongoing activity, require the highest levels of self-initiation. The author argued that J.B.'s PM deficits were related to problems with initiation which in turn is associated with difficulties in attentional control. Namely, J.B. was believed to show PM deficits which resembled deficiencies in Norman and Shallice's (1986) SAS. Shallice (1982) argued that deficient working of the SAS can explain problems with the formation, initiation and modification of plans, as it is responsible for prioritisation and control of action schemas which compete for attentional resources. Moreover, Shallice suggested that problems with SAS could result in action schemas being selected on the basis of contention scheduling, which selects schemas that are strongly triggered by the environment. Therefore, behaviour of an individual whose SAS is not functional was argued to be easy to predict. Namely, if an environmental situation (e.g. task) provides strong triggering of a schema, it was argued that it will not be possible to prevent the schema from being selected. This explanation could be applied to the data from the time-based PM tasks involving cognitively demanding ongoing tasks as individuals with dyslexia have been argued previously to have problems with SAS (e.g. Smith-Spark & Fisk, 2007). It could be argued that individuals with dyslexia were unable to break out from performance of the ongoing tasks which involved the additional updating tasks as those provided stronger triggering than the PM tasks. This in turn could have resulted in the difficulty in preventing the action schema related to performing the ongoing tasks from being selected, resulting in PM deficits and fewer time checks in dyslexia. This again could support the claim that there is a SAS deficit in dyslexia (e.g. Smith-Spark & Fisk, 2007).

In line with this reasoning individuals with dyslexia would not have a worse performance on the ongoing tasks which are overriding the activation of the other tasks (i.e. time checking and PM tasks). This was the case in the time-based experiment where participants with dyslexia did not differ significantly in their accuracy of performance on the primary and secondary (updating) ongoing tasks, but made fewer time checks and had a poorer performance on the PM task compared to controls. On the contrary, the ongoing tasks used in event-based experiments could be argued to provide triggering which was similar or weaker than the triggering provided by the event-based PM activities (focal PM tasks in particular). Thus, the ongoing tasks may not be overriding the triggering of the PM tasks. This could be argued to be related to the difficulty of the ongoing tasks used in the time- and event-based PM experiments, as the ongoing tasks used in the event-based experiments were generally easier than the ones used in the time-based PM experiments. Namely, difficult ongoing tasks may be argued to require more attention in comparison to the easier ongoing tasks. This could explain why individuals with dyslexia demonstrated a deficit in the time-based PM task but not in the event-based experiments. This reasoning is in agreement with literature suggesting problems with inhibition of attention drawing tasks in dyslexia (e.g. Palladino et al., 2001) as well as with the findings suggesting performance deficits in cognitively demanding tasks (e.g. Nicolson & Fawcett, 1990).

The problems with the SAS in dyslexia are also related to WM, as the SAS has been previously linked with the CE component of WM model (Baddeley, 1986). Individuals with dyslexia have been reported to have CE impairments (e.g. Jeffries & Everatt, 2004; Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007; see Chapter 2 for discussion). The CE is responsible for controlling the attentional system and therefore a deficit of CE in individuals with dyslexia could be also argued to be related to problems with self-initiated attention allocation and ultimately with time-based PM deficits. A study conducted by Marsh and Hicks (1998) found that tasks which are cognitively taxing on the CE component of WM reduced PM performance. Thus, PM problems in dyslexia found in the time-based experiment, where the two experimental conditions involved additional ongoing tasks employing CE, could be explained by CE deficits in dyslexia. Furthermore, Martin and Schumann-Hengsteler (2001) argued that limited WM resources are the underlying factor for inter-individual differences in PM tasks found in older adults. This argument was based on their study which showed that the extent of the age related deficit in PM task is dependent on the extent to which a PM task makes demands on the processing resources of the WM. They found a significantly greater age related deficit in tasks with high overall cognitive demand. A similar underlying factor may therefore account for group differences in the cognitive load manipulation of the ongoing task performed in this thesis, as the time-based PM tasks involving overall higher cognitive load could be argued to result in PM deficits seen in dyslexic sample. Thus, one could argue that the time-based PM deficit found in dyslexia supports problems in WM reported in dyslexia (e.g. Smith-Spark & Fisk, 2007).

The results from the event-based task involving a longer time interval (one week) as well as from the time-based tasks could suggest more involvement of conscious cognition i.e. planning or active monitoring of time which are argued to be executive functions (Miyake et al., 2000). Planning has been argued to be a one of the deficits associated with dyslexia (e.g. McLaughlin et al., 2002; Weyandt et al., 1998). Smith-Spark et al. (2004) found that individuals with dyslexia reported themselves to have planning and organisation difficulties. Further support for deficits in executive function of planning has been found by Reiter et al. (2005) and thus it is possible that these PM deficits found in this thesis support the deficit in planning and more generally the deficit in EF reported in dyslexia.

8.2.3.3. Cerebellar deficit theory

Researchers reported problems with time estimation perception in dyslexia (e.g. Augur, 1985; McLoughlin et al., 1994; 2002; Gilroy & Miles, 1996). Ivry and Keele (1989; cited in Nicolson & Fawcett, 2010) linked time estimation deficits to the cerebellum, as patients with cerebellar lesions showed specific deficits in time estimation. Nicolson et al. (1995) argued that individuals with dyslexia showed the same time deficits and suggested that this may be underpinned by cerebellum deficits. In order to be able to perform time-based PM tasks (at the appropriate time) one needs to rely on an “internal clock” to estimate time in order to initiate checking of the time (i.e. look at the clock) which acts as a prompt for the PM activity needed for successful time-based PM performance. Thus, poor time estimation could lead individuals with dyslexia to poor time-based PM task performance and one could argue that the finding showing less time checks and poorer time-based PM performance in dyslexia compared to controls, supports the cerebellar deficit theory (e.g. Nicolson et al., 2001). Thus, it could be argued that the problem with time estimation claimed by the cerebellar deficit theory leads to problems with time checking i.e. either checking the time too late or too early or not checking the time frequently enough in order to perform the time-based PM task successfully.

The result from MIST (Study 3) could be argued to be in line with this reasoning, as individuals with dyslexia committed more loss of time errors. Therefore, it could be reasoned that individuals with dyslexia are poorer at time estimation, as they have been found to provide the correct response but at the incorrect time. Misjudging the time passed since last checking the clock could have led individuals with dyslexia to make more loss of time errors and subsequently result in poorer time-based PM performance. Furthermore, these arguments are in line with the frontal lobe functioning deficits found in dyslexia (e.g. Brosnan et al., 2002) as frontal lobe functioning was found to predict the accuracy of time estimation in the context of PM task performance (McFarland & Glisky, 2009).

8.2.3.4. Processing speed

On the basis of no group differences in performance on the additional ongoing tasks involving phonologically-based and visuo-spatially-based updating tasks, it could be argued that the group of individuals with dyslexia did not portray deficits solely with phonological skills, as was argued by the phonological deficit hypothesis (e.g. Vellutino & Scanlon, 1987) or the double deficit hypothesis (e.g. Wolf & Bowers, 2000). However, it is possible that the phonologically-based updating tasks did not tap into phonological skills strongly enough to reveal the dyslexia-related deficit. Nevertheless, the double deficit hypothesis has also argued for a processing speed deficit in dyslexia. All of the experimental tasks conducted in this thesis revealed that participants with dyslexia had slower RTs compared to controls. The general pattern of slower RT’s found in the experimental work is in line with the processing speed deficit argued by the double deficit hypothesis (e.g. Wolf & Bowers, 1999). These results also support the information processing speed deficit in dyslexia (Fawcett & Nicolson, 1994; 1995a; 1995b) and the large body of dyslexia research which has identified a deficit in the speed of processing of visual stimuli (e.g. Denckla & Rudel, 1976; Wagner et al., 1993; McBride-Chang & Manis, 1996; Wolf & Bowers, 1999). It is possible that the slower RTs indicate a more general processing problem which may be linked to EF problems which have been found in dyslexia (e.g. Brosnan et al., 2002; Booth et al., 2010; Smith-Spark & Fisk, 2007). This reasoning is in line with the sluggish attentional shifting in individuals with dyslexia as argued by Hari and Renvall (2001). In their review of research related to processing speed of rapid stimulus sequence tasks they found that individuals with dyslexia were slower when switching attention between a variety of tasks. They claimed that the reason for individuals with dyslexia being slower when disengaging from one item to engage in the next item was related to sluggish attentional shifting. Thus, the findings revealing slower RTs in dyslexia could be argued to be compatible with this explanation related to deficient switching of attention. Norman and Shallice's (1986) SAS is responsible for attention allocation and thus this deficit in switching of attention is also related to deficits in functioning of SAS in dyslexia (as discusses previously). In addition, slower processing speed in individuals with dyslexia has been argued to be representative of automatisation deficits in dyslexia (Nicolson & Fawcett, 2008). Therefore, it could be argued that the slower RTs found in dyslexia in this thesis not only support the processing speed deficits reported in dyslexia, but also support the automaticity/cerebellum deficit hypotheses as well as broader cognitive deficits in dyslexia (Nicolson & Fawcett, 1990; Nicolson et al., 2001). This is similar to what was argued by other researchers (e.g. Smith-Spark & Fisk, 2007; Varvara et al., 2014) who proposed that dyslexia is underpinned by broader higher-order cognition deficits. These broader cognitive deficits could in turn underpin the worse PM performance in dyslexia when compared to age- and IQ-matched controls.

8.2.3.5. Implications for dyslexia theory more broadly

The results of this thesis suggest that deficits in developmental dyslexia are not limited to phonological skills as has been argued by the phonological core deficit hypothesis of dyslexia (e.g. Frith, 1985; Ramus, 2003; Snowling, 2000; Stanovich, 1988; Vellutino, 1979; Vellutino et al., 2004), since this thesis showed that adults with developmental dyslexia have deficits in PM tasks. A similar point of view has been presented by other researchers (e.g. Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007; Swanson, 2006; Varvara et al., 2014). Nevertheless, it could be argued that language is still involved in encoding instructions and intentions to act upon these instructions. However, the results from the retrospective recognition questionnaire that was used as a part of MIST showed that participants understood PM instructions. Moreover, participants with dyslexia maintained a good level of accuracy on the ongoing tasks which demonstrated that participants understood what was required of them. Therefore, it could be argued that the phonological processes required for encoding of instructions and intentions were not responsible for PM deficits in dyslexia. This supported the claim that individuals with dyslexia have deficits which are not limited to phonological skills i.e. PM or CE/EF deficits which manifest themselves on PM tasks.

It could be argued that the results which support SAS, inhibition, switching, planning and CE deficits in dyslexia, discussed in this section, point towards a more general problem with EF in individuals with dyslexia. This has been argued previously by other researchers (e.g. Smith-Spark & Fisk, 2007; Varvara et al., 2014) and could be supported by the results from this thesis as it was demonstrated that the results from this thesis support the deficits in different executive functions reported previously in dyslexia (e.g. inhibition, switching and WM).

Previous research has shown short-term memory/WM problems in adults with developmental dyslexia (e.g. Olson and Datta, 2002; Smith-Spark et al., 2003; Smith-Spark & Fisk, 2007; Varvara et al., 2014). The findings from the research carried out within this thesis contributed an original aspect to the dyslexia literature in that it showed that the problems with memory reported in dyslexia previously expand beyond short-term memory/WM problems, to future thinking in the form of PM. This is a very important finding which broadens the theoretical foundation of dyslexia and can be translated into practical implications for individuals with dyslexia.

8.3. Future research direction

The findings from this thesis indicated that there are time-based PM deficits in dyslexia. Nevertheless, more research is recommended in order to further investigate the conditions and processes which are responsible for these PM deficits. This section considers some propositions for future research in order to extend further the implications for literature discussed in previous section (section 8.2.).

It is suggested that future research investigates whether there are any PM deficits in adults with developmental dyslexia in event-based experiments with complex ongoing tasks drawing on attentional and executive resources. It is possible that when a cognitively demanding ongoing task is used in an event-based PM experiment, it may reveal a PM deficit in adults with dyslexia. For example, a similar ongoing task may be used as in the ongoing task load manipulation of the time-based PM. Moreover, it may be suggested to employ a similar paradigm to the one used by Einstein et al. (1995) or Martin et al. (2003) who embedded both time- and event-based PM tasks in one ongoing activity. Martin et al. (2003) used a multitask PM paradigm (MTPM) involving a mixture of six time- and event-based PM activities, which required planning during the intention formation phase and was argued to rely highly on prefrontal functioning.

A paradigm in which both time- and event-based PM tasks are embedded in one ongoing activity that draws strongly on a cognitive resources/relies strongly on EF, would enable further investigation of underlying processes that may be responsible for PM deficits in dyslexia. Einstein et al. (1995) argued that the reason behind finding greater age related deficits in time-based PM tasks compared to event-based PM tasks is related to the greater involvement of self-initiation in time-based tasks. Time-based PM tasks have been argued to involve the highest levels of self-initiation, due to the need for self-initiation of monitoring processes (e.g. Einstein & McDaniel, 1990; Groot et al., 2002) and self-initiation of an interruption of an ongoing task (Cockburn, 1995). Thus, if time-based PM problems in dyslexia are still found in a task with both time- and event-based PM tasks that are embedded in one complex ongoing activity, this could lend more support to the rationale presented in the previous section (section 8.2.), that the PM deficit in dyslexia is underpinned by problems with self-initiation and EF. McFarland and Glisky (2009) showed that self-initiated monitoring is controlled by prefrontal functioning and individuals with dyslexia have been found to have deficits in frontal functioning (Swanson, 2006). Thus, if there are more self-initiated processes required by time-based PM tasks, individuals with dyslexia should also reveal time-based PM deficits in tasks that directly compare time- and event-based PM (with the same complex ongoing activity). This should be especially profound in a PM paradigm with a complex ongoing task as individuals with dyslexia have been reported to perform worse on complex tasks due to the inability to consciously compensate for their performance deficits (Nicolson & Fawcett, 1990). Thus, such an extension of the current findings may be able to extend the claims made within this thesis in regards to problems with EF or cognitive capacity in dyslexia, as argued by Nicolson and Fawcett (1990), Smith-Spark and Fisk (2007) or Varvara et al. (2014). Moreover, self-initiation of monitoring and inhibition/switching processes (reasoned to be involved more in time-based PM than in event-based PM) could be also argued to be related to SAS which enables selection of the desired response by activation or inhibition of values of behavioural schemas (Norman & Shallice, 1986). Thus, if individuals with dyslexia are found to have deficits on time-based PM tasks in a paradigm allowing for the direct comparison of time- and event-based PM, one could argue that it is the deficit in SAS in dyslexia that is underpinning the poor performance. Thus, a paradigm allowing a direct comparison of time- and event-based PM embedded in a complex ongoing activity would establish whether factors such as SAS, inhibition, switching, cognitive capacity or EF deficits determine PM performance in dyslexia. Based on the literature suggesting deficits in these processes/models in dyslexia, this more in depth investigation of the two types of PM would also facilitate an investigation to find if these processes/models (self-initiation, SAS, involvement of EF/cognitive resources) are more relevant to time-based PM in comparison to event-based PM.

In order to investigate further exactly which executive functions underlie PM deficits in dyslexia, it is recommended to include measures of EF. These could be used in order to investigate which EF would predict PM performance in dyslexia. In particular, it could be suggested to measure inhibition and task switching abilities. It is important to investigate EF abilities in relation to PM performance in dyslexia as there is a large body of literature suggesting EF deficits in dyslexia (e.g. Smith-Spark & Fisk, 2007; Varvara et al., 2014) and EF has been found to predict PM performance (Martin et al., 2003).

Furthermore, an experimental design could be developed to enable investigation of PM performance when the ongoing task is well within ones EF abilities and just beyond them. A prior measurement of EF abilities would have to be performed in order to achieve this. For example, a similar updating task to that used in the ongoing task load manipulation (time-based experiment) could be used in order to establish the EF abilities. Namely, if one is able to correctly recall up to six locations of red frames surrounding pictures they would be considered to have a span of six. This span could be then used to design two versions of PM tasks which could incorporate similar ongoing tasks, but one version would require this participant to recall the last four locations (i.e. within span) and the other last eight (beyond span). In this way the first condition would present a task which would be well within this participant's EF abilities whereas the second condition would represent a task that goes beyond his or her EF abilities.

This titration procedure would have to be performed individually for each participant. This would allow researchers to see whether EF abilities have an effect on PM performance. Also, in this way, the Nicolson and Fawcett's (1990) automaticity theory could be put to the test. Nicolson and Fawcett stated that when participants with dyslexia are given a task that is within their abilities, they will be able to mask the deficit in automatisation. However, when the task goes beyond their abilities, a clear deficit will be revealed. This titration procedure would allow to test directly the DAD hypothesis in PM performance and dyslexia.

Moreover, it would be also very interesting to investigate both types of PM in children with developmental dyslexia also including the manipulation of task complexity and measurements of EF under different conditions (experimental, semi-naturalistic and naturalistic). This would allow to investigate whether deficits in PM are present in children with dyslexia as well as provide an insight into the development of PM. Namely, it would allow to see if there are differences in the development of PM in children with and without dyslexia as this area is still unexplored.

It could be also investigated whether a manipulation of task complexity might reveal a PM deficit in adults with developmental dyslexia when more everyday life-like PM measures are used. For example, the ongoing task used in the MIST could be made more complex by adding an additional ongoing task. The ongoing task (the word search puzzle) could be replaced by another task such as the one used by Martin and Schumann-Hengsteler (2001). They used the Mastermind game involving logical deduction (see e.g. Best, 1990; Laughlin, Lange & Adamopoulos, 1982). The use of this game allowed the authors to manipulate the difficulty of the ongoing task by increasing the amount of information and varying the complexity of feedback rules. Another possibility is to adopt the Rendell and Craik's (2000) Virtual Week measure of PM and try to vary the cognitive demands of the ongoing task which would allow an everyday PM investigation with varying task complexities.

Also if this thesis was to be carried out again, the stimuli employed in the event-based experiments could be selected accounting for ratings of picture saliency or in line with Scullin et al. (2010; experiments 2a and 2b) where the researchers identified cues which were fairly equivalent in terms of the monitoring difficulty. Once this is established, the focal PM tasks could involve highly salient PM cues which were argued to be more likely to result in automatic retrieval of PM intention in comparison to non-salient PM cues, which could be employed in the non-focal PM experiment, as these have been argued to be more likely to rely on monitoring. This could be combined with more cognitively demanding ongoing task as suggested previously. This would then test the spontaneous retrieval versus monitoring theories of PM further and could reveal an event-based PM deficit in dyslexia in the non-focal design, as hypothesised in Chapter 6. Future research should investigate PM cue saliency in relation to dyslexia.

In addition, if the thesis was to be replicated, a 24 hour delayed naturalistic event-based task would have been administered to accompany the 24 hour time-based PM task which forms a part of the MIST scale. This would enable a direct comparison between the two types of PM in every-day life in naturalistic settings. The event-based naturalistic task involving 24 hours delay was not used in the current thesis, as Raskin's (2004) standardised test (MIST) was used for an initial exploration of the range of PM in dyslexia (and no diversion from the standardised measure was advisable at this stage).

A further probe into PM in dyslexia could include a PM design which would enable experimenters to pinpoint the exact phase or phases of PM where the deficits related to dyslexia are the most prominent. Martin et al. (2003) used a task which allowed them to focus on intention formation and intention execution stages in a demanding task setting. They employed the MTPM task involving a mixture of time- and event-based PM activities, which required planning during the intention formation phase and was argued to rely largely on prefrontal functioning. A similar task could be used to investigate the PM deficits found in dyslexia as these could be related to failures at the intention initiation or execution stages, but may also be well at the intention formation stage. It would be interesting to manipulate cognitive load at the intention formation stage or similarly to Martin et al. (2003), employ a task drawing strongly on executive resources at the intention formation stage in order to see if this would have a diverse effect on PM performance in dyslexia. This could be also be performed by either increasing the cognitive load by having to perform an additional ongoing task while encoding the intention or by increasing cognitive load by a larger number of intentions to be encoded at once. On the other hand, the increased load at intention initiation stage could take form of a cognitively demanding ongoing task whereas increase of cognitive load at the intention execution stage could involve dividing attention at this stage. This proposition would enable further research to specify the exact stage of PM tasks where high cognitive load has a negative effect on PM performance. Furthermore studies (e.g. Guynn & McDaniel, 2007; McDaniel et al., 2004, Experiments 2 and 3) suggested that dividing attention in tasks, which rely on spontaneous retrieval does not reduce PM performance. Event-based PM tasks have been argued to rely on spontaneous retrieval (Einstein & McDaniel, 1996). Thus, one could argue that if no negative effect on event-based PM performance is found when ongoing tasks involving dividing of attention during intention of initiation stage is employed, this could support the spontaneous retrieval theory of event-based PM tasks (Einstein & McDaniel, 1996).

The stages of PM (i.e. intention formation, initiation and execution) could be also investigated in more naturalistic settings. It would be interesting to investigate the influence of environment in the different stages of PM. Both event- and time-based PM tasks can be triggered by environmental cues such as clocks or an objects reminding one about the PM activity. The saliency of PM cues (e.g. clock) is related to the strength of formed associations at the intention formation stage. On this basis, the environment can interact with the formed intentions (if the formed associations are strong enough) in order to initiate the PM retrieval. Thus the environment and the context in which the task is to be performed is important in PM tasks and therefore, worth investigating further. Namely, it may be easier if the context triggers the PM task compared to when it does not. By using the same setting for both tasks, i.e. asking participants to form a PM intention and to perform the PM task in the kitchen of a house, may result in better PM performance, in comparison to asking participants to perform the PM task in a different room or setting than the place where the intention was formed.

The role of distractors in PM would be another area which could be investigated further in relation to dyslexia. Considering that individuals with dyslexia have been reported to be vulnerable to distractors (e.g. Palladino et al., 2001), it would be interesting to investigate whether providing distractors would hinder the PM performance of individuals with dyslexia more than controls.

Motivation for performance on PM tasks would be especially interesting to investigate. It could be argued to be an important factor when investigating PM in dyslexia, as one may reason that individuals with dyslexia may be more motivated to complete PM tasks for two reasons. Namely, individuals with dyslexia may be more motivated in general in order to achieve their goals due to their performance deficits hindering their achievements on different tasks. This in turn could play out in PM tasks as individuals with dyslexia may be more motivated to complete them. Another possibility is that individuals with dyslexia could be more motivated as this research is about dyslexia and they may be even taking part in research to find out more about dyslexia in a first place. In comparison, there is also the possibility that individuals without dyslexia may not be as interested in taking part in dyslexia research as individuals with dyslexia, especially if they are doing it as a part of their university course requirement (i.e. for participation points). Thus, there is a possible bias in terms of individuals with dyslexia having a higher level of motivation for taking part in dyslexia research. This in turn could result in better performance of individuals with dyslexia than it would have been in their everyday lives. One solution to this problem would be to offer a prize to be won for a randomly selected person who has completed the PM tasks successfully. This could ensure that control participants maintain motivated also. Further research in this direction is recommended to see if motivation has an effect on PM performance in dyslexia.

Another idea for further research is related to the results from Study 2 (PMQ), which indicated that individuals with dyslexia use memory aiding techniques. Namely, it would be interesting to establish if individuals actually rely on memory aiding techniques more than controls, as stated in the self-report questionnaire study and if these techniques are used effectively. In addition, the use of memory aiding strategies in real life conditions could be examined using naturalistic investigation methods to see if they improve PM performance in individuals with dyslexia. In such a study, participants would have to be asked after the study if they had used any memory aiding techniques. This study could investigate which memory techniques would benefit individuals with dyslexia the most. Moreover, further applied research investigating how best to support people with dyslexia in the workplace is needed.

8.4. The bigger picture: Implications for everyday life in adults with dyslexia

The results from this thesis suggested that the adverse effects of dyslexia are not restricted to an early age or even to educational surroundings (reading and writing) or a particular specific processing domain (i.e. phonological or visuo-spatial), but persist throughout the life span, and under certain conditions affect the ability to carry out intentions in the future.

In order to support individuals with dyslexia, it could be suggested that adults with dyslexia would benefit from using electronic calendars with the option of an alarm reminder. Even though individuals with dyslexia reported to use more memory aiding techniques than controls (Study 2), it would be important to ensure that these are used effectively and that participants with dyslexia engage with these techniques e.g. a reminder on a mobile telephone is only useful if the individuals has the telephone with them. Effective use and engagement with memory aiding techniques would act as a reminder which would negate the need for self-initiation of PM activity and ultimately result in better PM in dyslexia. Memory aiding technologies would play a role of external cognition (Scaife & Rogers, 1996) which would help individuals with dyslexia manage their daily activities involving PM. In addition, it is recommended that the awareness of the adverse effects of cognitive overload on PM should be raised in the dyslexic population. Individuals with dyslexia could be advised on the best coping strategies and technological advances to help them remember prospectively. This could be supported by practitioners responsible for assessments of needs of individuals with dyslexia studying at universities. They could be making recommendations for Student Finance England with regards to the needs of dyslexic individuals for the purposes of the Disabled Students' Allowances (Disabled Students' Allowances, 2014).

Raising employers' awareness of the PM deficit of adults with developmental dyslexia in cognitively demanding situations could be used to support individuals with dyslexia in the work place. The Equality Act 2010 (Equality Act 2010, 2010) requires reasonable adjustments or support at work for individuals with dyslexia which could include helping individuals with dyslexia understand their PM difficulties and the development of some coping strategies. Introducing coping strategies to help individuals with dyslexia with their PM problems could make their everyday lives easier and help them succeed in their chosen career. Therefore employers and occupation health professionals need to be aware and understand that individuals with dyslexia may have time-based PM deficits. They need to be trained on how to best support people with dyslexia and be made aware of the types of support available (e.g. in the form of memory aids or bespoke solutions). For instance, in addition to setting a meeting at a future date through email, employers could implement meeting bookings via calendar software (e.g. Outlook calendar) which has the ability to place a reminder on the employee's computer desktop screen several times prior to this meeting e.g. 1 hour and 10 minutes. This reminder could also be synchronised with employee's mobile telephones and other devices.

Problems with PM can play out at work in many ways. Some ways in which PM failures can play out in a work place has already been outlined in an anecdotal vignette in Bartlett and Moody (2000). The authors of this book have a lot of experience working with adults with dyslexia on a daily basis. The vignette entitled “A good day at the office?” describes a day spent at the office by Mr Smith. In this one page description shadowing Mr Smith’s day there are three PM failures experienced by Mr Smith i.e. Mr Smith forgets to take some important papers from home and then he also forgets to send someone vital information and then he finally misses a meeting that he intended to go to. In addition, Bartlett and Moody (2000) state that adults with dyslexia are notorious for missing appointments and failing to meet deadlines. Even though Bartlett and Moody (2000) did not explicitly name these anecdotal problems observed in individuals with dyslexia as PM problems, those clearly resemble PM difficulties and provide a good demonstration of how PM problems could play out in the work place. On the basis of the current thesis, individuals with dyslexia may find particularly difficult to cope with situations involving time-based PM tasks. For example, individuals with dyslexia may forget to ring back a customer that they could not reach earlier (telephone engaged or not answered) or miss work meetings. The more serious PM failures could result in disciplinary action taken against the employee. This in turn, could result in failure in his or her career and even risk to the general well-being of individuals with dyslexia. Even the more mundane PM failures could result in lack of progression at work.

Thus, employers should be encouraged to make every effort to support individuals with dyslexia by putting checks in place in order to account for PM deficits in individuals with dyslexia. Scheduling and timetables with reminders could be used to support these PM difficulties in dyslexia to ensure that time-based PM tasks are converted to event-based tasks whenever possible to enhance work place effectiveness and support career progression.

8.5. Overall conclusion

To conclude, adults with dyslexia overall showed an awareness regarding their own deficits in PM (established using self-reports). The PM deficits in adults with dyslexia seem to also play out in everyday life. It can be also argued on a number of tasks (naturalistic, MIST and experimental) that dyslexia-related PM deficits are generally more related to time-based PM than event-based PM. These have been linked to EF/SAS deficits in dyslexia. In addition, on the basis of the range of tasks used in this thesis, it is possible that PM tasks involving greater time intervals between intention formation and execution are more likely to result in PM deficits in dyslexia.

The event-based experiments did not show any PM deficits in adults with developmental dyslexia. However, it is uncertain whether these deficits are present in dyslexia or whether they were not revealed due to task complexity in the event-based experiments not being sufficiently demanding. It is possible that a PM deficit might reveal itself in event-based experiments under greater cognitive task demands (e.g. greater ongoing tasks demands). Thus, an event-based experimental investigation of PM involving high cognitive load is recommended in order to examine its effect on developmental dyslexia in adulthood.

The current thesis explored PM in adults, as PM failures have more of a profound impact on lives of adults compared to children, since children often rely on care givers with regards to the tasks that they need to remember to perform in the future. Thus, as a first point of reference it was appropriate to employ adults with developmental dyslexia to investigate how dyslexia can impact on PM in everyday life. Further research involving children with developmental dyslexia is recommended in order to examine if there are different trajectories to development of PM in people with dyslexia compared to these who do not have dyslexia as this area has not been explored thus far.

References

Abegg, M., Manoach, D. S., & Barton, J. J. S. (2011). Knowing the future: Partial foreknowledge effects on the programming of prosaccades and antisaccades. *Vision Research 51,* 215-221.

Ackerman, P. T., & Dykman, R. A. (1993). Phonological processes, confrontational naming, and immediate memory in dyslexia. *Journal of Learning Disabilities, 26(*9), 597-609.

Alexander-Passé. A. (2006). How Dyslexic Teenagers Cope: An investigation of Self-esteem, Coping and Depression. *Dyslexia, 12*, 256-275.

Altgassen, M., Koban, N., & Kliegel, M. (2012). Do adults with autism the spectrum disorder compensate in naturalistic prospective memory tasks? *Journal of Autism and Developmental Disorders, 42,* 2141-2151.

Altgassen, M., Vetter, N. C., Phillips, L. H., Akgun, C., & Kliegel, M. (2014). Theory of mind and switching predict prospective memory performance in adolescents. *Journal of Experimental Child Psychology,* doi: 10.1016/j.jecp.2014.03.009.

Anderson, V. (1998). Assessing executive functions in children: Biological, psychological and developmental considerations. *Neuropsychological Rehabilitation, 8,* 319-349.

Ardila, A., Pineda, D., & Rosselli, M. (2000). Correlation between intelligence test scores and executive function measures. *Archives of Clinical Neuropsychology, 15,* 31-36.

Atkinson, R. C., & Shiffrin, R. M. (1968). "Chapter: Human memory: A proposed system and its control processes". In Spence, K. W., & Spence, J. T. *The psychology of learning and motivation* (Volume 2). New York: Academic Press. pp. 89–195.

Atkinson, R.C. & Shiffrin, R.M. (1971). The control of short-term memory. *Scientific American*, *225*(2), 82-90.

Augur, J. (1985). Guidelines for teachers, parents and learners. In M. Snowling (Ed.), *Children's written language difficulties* (pp. 147-170). Windsor: NFER-Nelson.

Bacon, A. M., Parmentier, F. B. R. & Barr. P. (2013). Visuospatial memory in dyslexia: evidence for strategic deficits. *Memory, 21*(2), 189-209.

Baddeley, A. D. (1986). *Working memory.* Oxford: Clarendon Press.

Baddeley, A. D. (1997). *Human memory: Theory and Practice (Revised Edition).* Hove: Psychology Press.

Baddeley, A. D. (2000). The episodic buffer: a new component of working memory. *Trends in Cognitive Sciences*, *4*(11), 417-423.

Baddeley, A. D. (2002). Fractionating the central executive. In D. T. Stuss (Ed.), *Principles of frontal lobe function* (pp. 246–260). London: Oxford University Press.

Baddeley, A. D. (2007). Working memory, thought and action. Oxford: Oxford University Press.

Baddeley, A., Eysenck, M. W. & Anderson, M. C. (2009). "Memory". New York: Psychology Press.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. Bower (Ed.), *The psychology of learning and motivation* (pp. 47-89). New York: Academic Press.

Baillieux, H., Vandervliet, E. J. M., Manto, M., Parizel, P. M., De Deyn, P. P., & Mariën, P. (2009). Developmental dyslexia and widespread activation across the cerebellar hemispheres. *Brain & Language, 108,* 122–132.

Baldwin, W. (2000). Information no one else knows: The value of self-report. In A.Stone, J. S. Turkkan, C. A. Bachrach, J. B. Jobe, H. S. Kurtzman, & V. Cain (Eds.), *The science of self-report, implications for research and practice* (pp. 3-7). New Jersey: Lawrence Erlbaum Associates.

Bargh, J. A., & Chartrand, T. L. (1999). The unbearable automaticity of being. *American Psychologist, 54*, 462–479.

Bargh, J. A., & Gollwitzer, P. M. (1994). Environmental control of goal-directed action: Automatic and strategic contingencies between situations and behavior. *Nebraska Symposium on Motivation ,41*, 71–124.

Bartlett, D., & Moody, S. (2000). *Dyslexia in the workplace.* London: Whurr Publishers.

Basso, D., Ferrari, M., & Palladino, P. (2010). Prospective memory and working memory: Asymmetrical effects during frontal lobe TMS stimulation. *Neuropsychologia, 48,* 3282-3290.

Baumeister, R. F., Bratslavsky, E., Muraven, M., & Tice, D. M. (1998). Ego depletion: Is the active self a limited resource? *Journal of Personality and Social Psychology, 74*, 1252–1265.

Best, J. (1990). Knowledge acquisition and strategy action in "Mastermind" problems. *Memory and Cognition, 18,* 54–64.

Bialystok, E., Craik, F. I., & Stefurak, T. (2008). Planning and task management in Parkinson's disease: Differential emphasis in dual-task performance. *Journal of the International Neuropsychological Society, 14*, 257–265.

Bisiacchi, P. S., Schiff, S., Ciccola, A., & Kliegel, M. (2009). The role of dual-task and task-switch in prospective memory: Behavioural data and neural correlates. *Nueropsychologia, 47*, 1362-1373.

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology, 54,* 579–616.

Booth, J. N., Boyle, J. M. E., & Kelly, S. W. (2010). Do tasks make a difference? Accounting for heterogeneity of performance of children with reading difficulties on tasks of executive function: Findings from a meta-analysis. *British Journal of Developmental Psychology, 28*, 133-176.

Borella, E., Carretti, B., & Pelegrina, S. (2010). The Specific Role of Inhibition in Reading Comprehension in Good and Poor Comprehenders. *Journal of Learning Disabilities, 43,* 541-552.

Bowers, P. G. (1995). Tracing symbol naming speed's unique contributions to reading disabilities over time. *Reading and Writing, 7*, 189-216.

Bowers, P. G., Wolf, M. (1993). Theoretical links among naming speed, precise timing mechanisms and orthographic skill in dyslexia. *Reading and Writing, 5,* 69-85

Brachacki, G. W. Z., Fawcett, A. J., & Nicolson, R. I. (1994). Adults with dyslexia have a deficit in voice recognition. *Perceptual and Motor Skills, 78*(1), 304-306.

Bradley, L., & Bryant, P.E. (1978) Difficulties in auditory organisation as a possible cause of reading backwardness. *Nature, 271*, 746-747.

Breneiser, J. E. (2008). Implementation intentions and cost in prospective memory retrieval. *Dissertation Abstracts International, 69*, 1352.

Breneiser, J. E. (2009). Implementation intentions and generative strategies in prospective memory retrieval. *North American Journal of Psychology Audience: Academic*, *11*(2), 401.

Broadbent, D. E., Cooper, P. F., Fitzgerald, P., & Parkes, K. (1982). The cognitive failures questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology, 21*, 1–16.

Brodal, A. (1981). The cerebellum. In A. Brodal (ed.), *Neurological Anatomy in Relation to Clinical Medicine* (pp. 294-393). Oxford: Oxford University Press.

Brosnan, M., Demetre, J., Hamill, S., Robson, K., Shepherd, H., & Cody, G. (2002). Executive functioning in adults and children with developmental dyslexia. *Neuropsychologia, 40*, 2144-2155.

Brown, W. E., Eliez, S., Menon, V., Rumsey, J. M., White, C. D., & Reiss, A. L. (2001). Preliminary evidence of widespread morphological variations of the brain in dyslexia, *Neurology, 56*, 781–3.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental Psychology 28,* 874-886.

Burgess, P., Gilbert, S., Dumontheil, I. (2007). Function and localization within rostral prefrontal cortex (area 10). *Philosophical Transactions of the Royal Society Biological Sciences, 362*, 887-899.

Burgess, P., Gilbert, S., Dumontheil, I., Simons, J. (2001). Hypothesis of rostral prefrontal cortex function. *Measuring the Mind*, 5, 217-248.

Burgess, P. W., Quayle, A., & Frith, C. D. (2001). Brain regions involved in prospective memory as determined by positron emission tomography. *Neuropsychologia, 39*, 545–555.

Burgess, P. W., Scott, S. K., & Frith, C. D. (2003). The role of the rostral frontal cortex (area 10) in prospective memory: A lateral versus medial dissociation. *Neuropsychlogia, 41,* 906-918.

Burgess, P. W., & Shallice, T. (1997). The relationship between prospective and retrospective memory: neuropsychological evidence. In M. A. Conway (Ed.), *Cognitive models of memory* (pp. 247-272). Hove, UK: Psychology Press.

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28,* 595-616.

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition, 91*, 77–111.

Castle, J. M., Riach, J., & Nicolson, T. (1994). Getting off to a better start in reading and spelling: The effects of phonemic awareness instruction within a whole language program. *Journal of Educational Psychology, 86,* 350-359.

Ceci, S. J., & Bronfenbrenner, U. (1985). Don't forget to take the cupcakes out of the oven: Prospective memory, time-monitoring and context. *Child Development, 56*, 152–164.

Chan, R. C. K., Qing, Y., Wu, Q., & Shum, D. (2010). Prospective memory in healthy Chinese people: The latent structure of the Comprehensive Assessment of Prospective Memory Questionnaire. *Neuropsychological Rehabilitation, 20*, 459–470.

Chan, R. C. K., Wang, Y., Ma, Z., Hong, X., Yuan, Y., Yu, X., Li, Z., Shum, D., & Gong, Q. (2008). Objective measures of prospective memory do not correlate with subjective complaints in schizophrenia. *Schizophrenia Research 103*, 229–239.

Chiappe, P., Hascher, L., & Siegel, L. (2000). Working memory, inhibitory control, and reading disability. *Memory and Cognition, 28*, 8–17.

Cheng, A., Eysel, U. T., & Vidyasagar, T. R. (2004). The role of the magnocellular pathway in serial deployment of visual attention. *European Journal of Neuroscience, 20*, 2188–2192.

Cockburn, J. (1995). Task interruption in prospective memory: a frontal lobe function? *Cortex, 31,* 87-97.

Cohen, A.- L., Jaudas, A., & Gollwitzer, P. M. (2008). Number of cues influences the cost of remembering to remember. *Memory & Cognition, 36*, 149-156.

Cona, G., Bisiacchi, P. S., & Moscovitch, M. (2013). The effects of focal and nonfocal cues on the neural correlates of prospective memory: Insights from ERPs. *Cerebral Cortex*. http://dx.doi.org/10.1093/cercor/bht116.

Crawford, J. R., Henry, J. D., Ward, L. A., & Blake, J. (2006). The prospective and retrospective memory questionnaire (PRMQ); Latent structure, normative data and discrepancy analysis for proxy-ratings. *British Journal of Clinical Psychology, 45*, 83-104.

Crawford, J. R., Smith, G., Maylor, E. A., Della Sala, S., & Logie, R. H. (2003). The Prospective and Retrospective Memory Questionnaire (PRMQ): Normative data and latent structure in a large non-clinical sample. *Memory, 11*, 261–275.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix & H. Hagendorf (eds.), *Human memory and cognitive capabilities: Mechanisms and performances* (pp. 409-422). Amsterdam: Elsevier.

Craik, F. I. M., Anderson, N. D., Kerr, S. A., & Li, K. Z. H. (1995). Memory changes in normal ageing. In A. D. Baddeley, B. A. Wilson & F. N. Watts (Eds.), *Handbook of memory disorders* (pp. 211–241). Chichester: Wiley.

Craik, F. I. M., & Bialystok, E. (2006). Planning and task management in older adults: Cooking breakfast. *Memory & Cognition, 34*, 1236–1249.

Craik, F. I. M., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. Trehub (eds.), *Advances in the study of communication and affect: Vol. 8. Aging and cognitive processes* (pp. 191-211). New York: Plenum.

Creasey, G.L. & Jarvis, P.A. (1987). Sensitivity to nonverbal communication among male learning disabled adolescents. *Perceptual and Motor Skills 64*, 873-874.

Crowder, B. K. (2013). An overview of working memory. *International Journal of Academic Research in Applied Science, 2*(5), 13-19.

Cuttler, C., & Graf, P. (2009). Sub-clinical compulsive checkers show impaired performance on habitual, event- and time-cued episodic prospective memory tasks. *Journal of Anxiety Disorders, 23,* 813–823.

Delprado, J., Kinsella, G., Ong, B., & Pike, K. (2013). Naturalistic Measures of Prospective Memory in Amnestic Mild Cognitive Impairment. *Psychology and Aging, 28*, 322-332.

Della Sala, S., Gray, C., Baddeley, A., Allamano, N., & Wilson, L. (1999). Pattern Span: a tool for unwelding visuo-spatial memory, *Neuropsychologia, 37,* 1189-1199.

Demonet, J. F., Taylor, M. J., & Chiax, Y. (2004). Developmental Dyslexia. *The Lancet , 363*, 1451-1460.

Denckla, M. B., & Rudel, R. G. (1976). Naming of object-drawings by dyslexic and other learning disabled children. *Brain and Language, 3*1-15.

Derrington, A. M., Krauskopf, J., & Lennie, P. (1984). Chromatic mechanisms in lateral geniculate nucleus of macaque. *The Journal of physiology, 357*, 241-65.

DeWitt, M. R., Hicks, J. L., Ball, B. H., & Knight, J. B. (2012). Encountering items previously paired with prospective memory target events can serve to reactivate intentions. *Journal of Cognitive Psychology, 24*, 981–990.

Disabled Students' Allowances (2014). Retrieved from https://www.gov.uk/disabled-students-allowances-dsas on the 14/03/2014

Dismukes, R. K., & Nowinski, J. L. (2005). Effects of ongoing task context and target typicality on prospective memory performance: The importance of associative cueing, *Memory, 13*(6), 649-657.

Dobbs, A. R., & Rule, B. G. (1987). Prospective memory and self-reports of memory abilities in older adults. *Canadian Journal of Psychology, 41*, 209–222.

Doyle, J. (1996). *Dyslexia: An introductory guide.* San Diego, CA: Singular Publishing Group, Inc.

Dykman, R. A., Ackerman, P. T., & Holcomb, P. J. (1985). Reading disabled and ADD children: Similarities and differences. In G. B. Gray & J. F. Kavanagh (Eds.), *Biobehavioural measures of dyslexia.* Baltimore: York Press.

d'Ydewalle, G., Bouckaert, D., & Brunfaut, E. (2001). Age-related differences and complexity of ongoing activities in time- and event-based prospective memory. *American Journal of Psychology, 114*, 411-423.

d'Ydewalle, G., Luwel, K., & Brunfaut, E. (1999). The importance of on-going concurrent activities as a function of age in time- and event-based prospective memory. *European Journal of Cognitive Psychology, 11,* 219-237.

Eden, G. F., VanMeter, J. W., Rumsey, J. M., Maisog, J. M., Woods, R. P., & Zeffiro, T. A. (1996). Abnormal processing of visual motion in dyslexia revealed by functional brain imaging. *Nature, 382*, 66-69.

Ehri, L.C. (1987) Learning to read and spell words. *Journal of Reading Behaviour, 19*, 5-31.

Einstein, G. O. & McDaniel, M. A. (1990). Normal aging and prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 717-726.

Einstein, G. O., & McDaniel, M. A. (1996). Retrieval processes in prospective memory: Theoretical approaches and some new empirical findings. In M. Brandimonte, G. O. Einstein, & M. A.McDaniel (Eds.), *Prospective memory: Theory and application* (pp. 115–141). Mahwah, NJ: Erlbaum.

Einstein, O., & McDaniel, M. (2005). Prospective memory: Multiple retrieval processes. *Current Directions in Psychological Science, 14,* 286-290.

Einstein, G. O., McDaniel, M. A., Richardson, S. L., Guynn, M. J., & Cunfer, A. R. (1995). Aging and prospective memory: Examining the influences of self-initiated retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 996-1007.

Einstein, G. O., McDaniel, M. A., Thomas, R., Mayfield, S., Shank, H., Morrisette, N., & Breneiser, J. (2005). Multiple Processes in Prospective Memory Retrieval: Factors Determining Monitoring Versus Spontaneous Retrieval. *Journal Of Experimental Psychology: General, 134*(3), 327-342.

Einstein, G. O., Smith, R. E., McDaniel, M. A., & Shaw, P. (1997). Aging and prospective memory: The influence of increased task demands at encoding and retrieval. Psychology and Aging, 12, 479–488.

Einstein, G. O., McDaniel, M. A., Manzi, M., Cochran B., & Baker, M. (2000). Prospective memory and aging: Forgetting intentions over short delays. *Psychology and Aging, 15,* 671-683.

Ellis, J. A. (1988). Memory for future intentions: Investigating pulses and steps. In M. M. Gruneberg, P. E. Morris, & R. N. Sykes (Eds.). *Practical aspects of memory: Current research and issues* (pp. 371–376). Chichester, England: Wiley.

Ellis, J. (1996). Prospective memory or the realization of delayed intentions: A conceptual framework for research. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 1-51). Hillsdale, NJ: Erlbaum.

Ellis, J., & Kvavilashvili, L. (2000). Prospective memory in 2000: Past, present, and future directions. *Applied Cognitive Psychology,* 1-9.

Ellis, J. & Milne, A. (1996). Retrieval cue specificity and the realization of delayed intentions. *Quarterly Journal of Experimental Psychology, 49*, 862-887.

Eysenck, M. W., Keane, M. T. (2005). Cognitive psychology: A student's handbook (5th ed.). New York: Psychology Press.

Facoetti, A., Lorusso, M. L., Paganoni, P., Cattaneo, C., Galli, R., & Mascetti, G. G. (2003). Thetimecourse of attentional focusing in dyslexic and normally reading children. Brain Cogn. 53, 181-184.

Facoetti, A., & Molteni, M. (2001). The gradient of visual attention in developmental dyslexia. *Neuropsychologia, 39*(4), 352-7.

Facoetti, A., Paganoni, P., Turatto, M., Marzola, V., & Mascetti, G. G. (2000). Visual-spatial attention in developmental dyslexia. Cortex 36, 109–123.

Facoetti, A., Turatto, M., Lorusso, M. L., & Mascetti, G. G. (2001). Orienting of visual attention in dyslexia: evidence for asymmetric hemispheric control of attention. Exp. Brain Res. 138, 46–53.

Fawcett, A. J., & Nicolson, R. I. (1994). Naming speed in children with dyslexia. *Journal of Learning Disabilities, 27,* 641-646.

Fawcett, A. J., & Nicolson, R. I. (1994). Speed of processing, motor skill, automaticity and dyslexia. In A. J. Fawcett & R. I. Nicolson (Eds.), *Dyslexia in children: Multidisciplinary perspectives* (pp. 157-190). London: Harvester Wheatsheaf.

Fawcett, A. J., & Nicolson, R. I. (1995a). Persistence of phonological awareness deficits in older children with dyslexia. *Reading and Writing, 7*, 361-376.

Fawcett, A. J., & Nicolson, R. I. (199b). Persistent deficits in motor skill for children with dyslexia. *Journal of Motor Behaviour, 27,* 235-241.

Fawcett, A. J., & Nicolson, R. I. (1998). *The dyslexia adult screening test (DAST).* London: The Psychological Corporation.

Fawcett, A. J., Nicolson, R. I., & Dean P. (1996). Impaired performance of children with dyslexia on a range of cerebellar tasks. *Annual Dyslexia, 46,* 259-83.

Fawcett, A. J., & Nicolson, R. I. (2004). Dyslexia: The role of the cerebellum. *Electronic Journal of Research in Educational Psychology, 2*(2), 35-58.

Felton, R. H., & Wood, F. B. (1989). Cognitive deficits in reading disability and attention disorder. *Journal of Learning Disabilities*, *22*, 3–22.

Finch, A. J., Nicolson, R. I., & Fawcett, A. J. (2002). Evidence for a neuroanatomical difference within the olivo-cerebellar pathway of adults with dyslexia. *Cortex*, *38*, 529–539.

Finucci, J. M., Guthrie, J. T., Childs, A. L., Abbey, H., & Childs, R. (1976). The genetics of specific reading disability. *Annals of Human Genetics*, *50*, 1-23.

Foy, J. G., & Mann, V. A. (2003). Home literacy environment and phonological awareness in preschool children: Differential effects for rhyme and phoneme awareness. *Applied Psycholinguistics, 24*(1), 59-88.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia* (pp. 301-322). London: Lawrence Erlbaum Associates Ltd.

Fuster, J. M. (1997). *The prefrontal cortex: Anatomy, physiology, and neuropsychology of the frontal lobe.* Philadelphia, PA: Lippincott-Raven.

Galaburda, A. M., & Livingstone, M. S. (1993). Evidence for a magnocellular defect in developmental dyslexia. *Ann N Y Acad Sci, 682,* 70-82.

Galaburda, A. M., Menard, M. T., & Rosen, G. D. (1994). Evidence for aberrant auditory anatomy in developmental dyslexia. *Proc Natl Acad Sci U S A. 91*(17), 8010-3.

Gathercole, S. E., & Baddeley, A. D. (1990). Phonological memory deficits in language disordered children: Is there a causal connection? *Journal of Memory & Language, 29,* 336 360.

Gilroy, D. E., & Miles, T. R. (1996). *Dyslexia at college* (2nd ed.). London and New York: Routledge.

Gevins, A., Smith, M.E., McEvoy, L. & D. (1997) High-resolution EEG mapping of cortical activation related to working memory: effects of task difficulty, type of processing, and practice. *Cereb. Cortex, 7,* 374–385.

Glisky, E. L., Polster, M. R., & Routhieaux, B. C. (1995). Double dissociation between item and source memory. *Neuropsychology, 9,* 229–235.

Godefroy, O., & Rousseaux, M. (1996). Divided and focused attention in patients with lesion of the prefrontal cortex. *Brain Cognition, 30,* 155–174.

Goel, V. & Grafman, J. (1995). Are the frontal lobesimplicated in “planning” functions? Interpreting data from the Tower of Hanoi. Neuropsychologia, 33, 623-642.

Gonneaud, J., Kalpouzos, G., Bon, L., Viader, F., Eustache, F., & Desgranges, B. (2011). Distinct and shared cognitive functions mediate event- and time-based prospective memory impairment in normal ageing. *Memory, 19*(4), 360–377.

Gordon, B. A., Shelton, J. T., Bugg, J. M., McDaniel, M. A. & Head, D. (2011). Structural correlates of prospective memory. *Neuropsychologia*, *49*(14), 3795– 3800.

Goschke, T. & Kuhl, J. (1993). Representation of intentions: Persisting activation in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 1211-1226.

Goschke, T., & Kuhl, J. (1996). Remembering what to do: Explicit and Implicit memory for intentions. In M. Brandimonte, G. O. Einstein, & M. A. McDaniel (Eds.), *Prospective memory: Theory and application* (pp. 53–91). Mahwah, NJ: Erlbaum.

Goswami, U. (2003). Why theories about developmental dyslexia require developmental designs*. Trends in Cognitive Sciences, 7,* 534-554.

Graf, P., & Uttl, B. (2001). Prospective memory: A new focus for research. *Consciousness Cognition*, *10*, 437–450.

Griffiths, Y. M., & Snowling, M. J. (2002). Predictors of Exception Word and Nonword Reading in Dyslexic Children: The Severity Hypothesis. *Journal of Educational Psychology, 94*(1), 34-43.

Groot, Y. C., Wilson, B. A., Evans, J., & Watson, P. (2002). Prospective memory functioning in people with and without brain injury. *Journal of International Neuropsychology, 8*(5), 645-654.

Guynn, M. J., & McDaniel, M. A. (2007). Target preexposure eliminates the effect of distraction on event-based prospective memory. *Psychonomic Bulletin and Review*, *14*, 484-488.

Guynn, M. J., McDaniel, M. A., & Einstein, G. O. (1998). Prospective memory: When reminders fail. *Memory & Cognition, 26,* 287–298.

Guynn, M. J., McDaniel, M. A., & Einstein, G. O. (2001). Remembering to perform actions: A different type of memory? In H. D. Zimmer, R. L. Cohen, M. J. Guynn, J. Engelkamp, R. Kormi-Nouri, & M. A. Foley (Eds.), *Memory for action: A distinct form of episodic memory?* (pp. 25–48). New York: Oxford University Press.

Hannon, R., Adams, P., Harrington, S., Fries-Dias, C., & Gibson, M. (1995). Effects of brain injury and age on prospective memory self-rating and performance. *Rehabilitation Psychology, 40,* 289–298.

Hari, R. (1995). Illusory directional hearing in humans. *Neurosci. Lett. 189,* 29–30.

Hari, R., & Renvall, H. (2001) Impaired processing of rapid stimulus sequences in dyslexia. *Trends in Cognitive Sciences, 5*(12), 525-532.

Hari, R., Valta, M., & Uutela, K. (1999) Prolonged attentional dwell time in dyslexic adults. *Neuroscience Letters, 271,* 202–204.

Hari, R., Renvall, H., & Tanskanen, T. (2001). Left minineglect in dyslexic adults. *Brain, 124*(7), 1373–1380.

Harris, J. E. (1984). Remembering to do things: A forgotten topic. In J. E. Harris & P. E. Morris (Eds.), *Everyday memory, actions, and absent-mindedness* (pp. 71-92). London: Academic Press.

Harris, J. E. & Wilkins, A. J. (1982). Remember to do things: A theoretical framework and an illustrative experiment. *Human Learning, 1,* 123-136.

Haslum, M. H. (1987). *Dyslexia in a national cohort of children.* Paper presented at the British Dyslexia Association conference, Current Research in Specific Learning Difficulties, London.

Hatcher, J., & Snowling, M. J. (2006). The Phonological representations Hypothesis of Dyslexia: From Theory to Practice. In G. Reid, & J. Wearmouth (Eds.), *Dyslexia and Literacy: Theory and Practice* (pp. 69-84). West Sussex, UK: John Wiley & Sons.

Hayes, S. C., Gifford, E. V., & Ruckstuhl, L. E. (1996). Relational frame theory and executive function: A behavioral approach. In G. R. Lyons & N. A. Krasnegor (Eds.), *Attention, memory and executive function* (pp. 279-306). Baltimore: Brookes.

Heaton, R. K., Chelune, G. J., Talley, J. L., Kay, G. G., & Curtiss, G. (1993). *Wisconsin Card Scoring Test Manual*. Odessa, FL: Psychological Assessment Resources.

Heffernan, T. M., Jarvis, H. H., Rodgers, J. J., Scholey, A. B., & Ling, J. J. (2001). Prospective memory, everyday cognitive failure and central executive function in recreational users of Ecstasy. *Human Psychopharmacology: Clinical and Experimental, 16*(8), 607-612.

Heffernan, T., Ling, J., & Bartholomew, J. (2004). Self-rated prospective memory and central executive deficits in excessive alcohol users. *Irish Journal of Psychological Medicine, 21*(4), 122-124.

Heffernan, T. M., Ling, J. J., Parrott, A. C., Buchanan, T. T., Scholey, A. B., & Rodgers, J. J. (2005). Self-rated everyday and prospective memory abilities of cigarette smokers and non-smokers: A web-based study. *Drug and Alcohol Dependence, 78*(3), 235-241.

Heffernan, T., & O'Neill, T. (2012). Time based prospective memory deficits associated with binge drinking: Evidence from the Cambridge Prospective Memory Test (CAMPROMPT). *Drug and Alcohol Dependence,* Available online 15 December 2011.

Heffernan, T., O'Neill, T., & Moss, M. (2010). Smoking and everyday prospective memory: A comparison of self-report and objective methodologies. *Drug and Alcohol Dependence 112*, 234–238.

Hektner, J., M. (2012). Developmental psychology. In M. R. Mehl, & T. S. Conner (Eds.), *Handbook of research method is s for studying daily life* (pp. 585-600). New York, USA: The Guilford Press.

Henry, J. D., MacLeod, M., Phillips, L. H., & Crawford, J. R. (2004). Meta-analytic review of prospective memory and aging. *Psychology and Aging, 19*, 27-39.

Helenius, P., Uutela, K., & Hari, R. (1999). Auditory stream segregation in dyslexic adults. *Brain, 122*, 907–913.

Helland, T., & Asbjørnsen, A. (2004). Digit span in dyslexia: Variations according to language comprehension and mathematics skills. *Journal of Clinical and Experimental Neuropsychology, 26*(1), 31-42.

Herrmann, D. J. (1984). Questionnaires about memory. In J. E. Harris & P. E. Morris (Eds.), *Everyday memory, actions and absent-mindedness* (pp. 133–151). London: Academic Press.

Hicks, J. L., Marsh, R. L. & Cook, G. I. (2005). Task interference in time-based, event-based, and dual intention prospective memory conditions. *Journal of Memory and Language 53*(3), 430-444.

Hoffmann, F. J. Sheldon, K. L., Minskoff, E. H., Sautter, S. W., Steidle, E. F., Baker, M. B. & Echois, L. D. (1987). Needs of learning disabled adults. *Journal of Learning Disabilities 20*, 43-48.

Holmes, G. (1939). The cerebellum of man. *Brain, 62*, 1-30.

Horn, S. S., Bayen, U. J., Smith, R. E., & Boywitt, C. D. (2011). The Multinomial Model of Prospective Memory. *Journal of Experimental Psychology, 58(3), 247–255.*

Humphrey, N. & Mullins, P. M. (2002). Self-concept and Self-Esteem in Developmental Dyslexia. *Journal of Research in Special Educational Needs, 2* (2), 1-13.

Hunt, R. R., & Toth, J. P. (1990). Perceptual identification, fragment completion, and free recall: Concepts and data. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 282–290.

Iles, J., Walsh, V., & Richardson, A. (2000). Visual search performance in dyslexia. Dyslexia, 6, 163–77.

Ito, M. (1990). A new physiological concept on cerebellum. *Revue Neurologique, 146*, 564-569.

Jeffries, S., & Everatt, J. (2004). Working memory: Its role in dyslexia and other specific learning difficulties. *Dyslexia: An International Journal of Research and Practice, 10*, 196-214.

Jenkins, J. J. (1979). For points to remember: A tetrahedral model of memory. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing in human memory* (pp. 429-446), Hillsdale, NJ: Erlbaum.

Jenkins, I. H., Brooks, D. J., Nixon, P. D., Frackowiak, R. S. J., & Passingham, R. E. (1994). Motor sequence learning – a study with Positron Emission Tomography. *Journal of Neuroscience, 14*, 3775-90.

Jorm, A. F. (1983). Specific reading retardation and working memory: A review. *British Journal of Psychology, 74,* 311-342.

Justus, T. C., & Ivry, R. B. (2001). The cognitive neuropsychology of the cerebellum. *International Review of Psychiatry, 13*, 276-282.

Kalat, J. W. (Ed.) (2007). *Biological Psychology* (9th ed.). Pacific Grove: Brooks/Cole.

Khan, A., Narendra S.K., Dixit, S. (2008). Cognitive load and task condition in event- and time-based prospective memory: an experimental investigation. *The Journal of Psychology*, 142(5), 517-532.

Kinsbourne, M., Rufo, D. T., Gamzu, E., Palmer, R. L., & Berliner, A. K. (1991). Neuropsychological deficits in adults with dyslexia. *Developmental Medicine and Child Neurology, 33*, 763–775.

Kirby, J.R., Silvestri, R., Allingham, B.H., & Parrila, R. (2008) Learning Strategies and Study Approaches of Postsecondary Students With Dyslexia. *Journal of Learning Disabilities, 41*(1), 85-96.

Kliegel, M. & Jäger, T. (2006). Can the prospective and retrospective memory questionnaire (PRMQ) predict actual prospective memory performance? *Current Psychology: Development, Learning, Personality, Social, 25*(3), 182-191.

Kliegel, M., Martin, M., McDaniel, M. A., & Einstein, G. O. (2001). Varying the importance of a prospective memory task: Differential effects across time- and event-based prospective memory. *Memory, 9*(1), 1–11.

Kliegel, M., Martin, M., McDaniel, M. A., & Phillips, L. H. (2007). Adult age differences in errand planning: The role of task familiarity and cognitive resources. *Experimental Aging Research, 33*, 145–161.

Kliegel, M., McDaniel, M. A., & Einstein, G. O. (2000). Plan formation, retention, and execution in prospective memory: A new approach and age-related effects. *Memory & Cognition, 28,* 1041-1049.

Kliegel, M. K., McDaniel, M. A., & Einstein, G. O. (2008). *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives.* NJ: Lawrence Erlbaum Associate.

Kliegel, M., Zimprich, D. & Eschen, A. (2005). What do subjective complaints in persons with aging-associated cognitive decline reflect? *International Psychogeriatrics, 17,* 1–14.

Kleitman, S., & Stankov, L. (2007) Self-confidence and metacognitive processes. *Learning and Individual Differences journal, 17* (2), 161-73.

Koriat, A., Ben-Zur, H., & Nussbaum, A. (1990). Encoding information for future enactment: Memory for to-be-performed versus memory for to-be-recalled tasks. *Memory and Cognition, 18,* 568-578.

Kronick, D. (1983). Social Development of Learning Disabled Persons. Toronto: Jossey-Bass.

Krupa, D. J., Thompson, J. K., & Thompson, R. F. (1993). Localization of a memory trace in the mammalian brain. *Science, 260*, 989-991.

Kusak, G., Grune, K., Hagendorf, H., and Metz, A.M. (2000) Updating of working memory in a running memory task: An event-related brain potential study. International *Journal of Psychophysiology, 39*, 51-65

Kvavilashvili, L. (1987), Remembering intention as a distinct form of memory. *British Journal of Psychology, 78*, 507-518.

Kvavilashvili, L., & Ellis, J. (1996). Varieties of intention: Some distinctions and classifications. In M. Brandimonte, G. Einstein, & M. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 23-51). Hillsdale, NJ: Erlbaum.

Kvavilashvili, L., & Fisher, L. (2007). Is time-based prospective remembering mediated by self-initiated rehearsals? Role of incidental cues, ongoing activity, age, and motivation. *Journal of Experimental Psychology: General, 136*, 112-132.

Lallier, M., Tainturier, M., Dering, B., Donnadieu,S., Valdois, S., & Thierry, G. (2010). Behavioral and ERP evidence for amodal sluggish attentional shifting in developmental dyslexia. *Neuropsychologia. 48*, 4125-4135.

Laasonen, M., Service, E. &Virsu, V.(2001). Temporal order and processing acuity of visual, auditory, and tactile perception in developmentally dyslexic young adults. Cogn. Affect.Behav. *Neurosci., 1*, 394–410.

Laasonen, M., Tomma-Halme, J., Lahti-Nuuttila, P., Service, E. & Virsu, V. (2000). Rate of information segregation in developmentally dyslexic children. *Brain Lang., 75*, 66–81.

Laughlin, P., Lange, R., & Adamopoulos, J. (1982). Selection strategies for "Mastermind" problems. *Journal of Experimental Psychology: Learning, Memory and Cognition, 8*, 475–483.

Leather, C., Hogh, H., Seiss, E. & Everatt, J. (2011). Cognitive Functioning and Work Success in Adults with Dyslexia. *Dyslexia, 17*, 327-338.

Leiner, H. C., Leiner, A. L., & Dow, R. S. (1991). Reappraising the cerebellum: what does the hindbrain contribute to the forebrain. *Behavioural Neuroscience, 103*, 998-1008.

Leiner, H. C., Leiner, A. L., & Dow, R. S. (1993). Cognitive and language functions of the human cerebellum. *Trends in Neuroscience, 16*, 444-447.

Lenkowsky, L.K. and Saposnek, D.T. (1978). Family consequences of parental dyslexia. *Journal of Learning Disabilities 11*, 47-53.

Leonard, C. M., Eckert, M. A., Lombardino, L. J., Oakland, T., Kranzler, J., Mohr, C. M. et al. (2001). Anatomical risk factors for phonological dyslexia. *Cereb Cortex; 11*, 148–57.

Levin, B. E. (1990). Organisational deficits in dyslexia: Possible frontal lobe dysfunction. *Neuropsychology, 6*(2), 95-110.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). Oxford: University Press.

Livingstone, M. S., Rosen, G. D., Drislane, F. W., & Galaburda, A. M. (1991). Physiological and anatomical evidence for a magnocellular defect in developmental dyslexia. *Neurobiology, 88*, 7943-7947,

Loft, S., Pearcy, B., & Remington, R. W. (2011). Varying the complexity of the prospective memory decision process in an air traffic control simulation. *Zeitschrift fu¨r Psychologie /Journal of Psychology, 219*, 7-84.

Lovegrove, W. J. (1993). Weakness in the transient visual system: a causal factor in dyslexia? In P. Tallal, A. M. Galaburda, R. R. Llinas, & C. von Euler, *Temporal information processing in the nervous system* (pp. 57-69). New York: New York Academy of Sciences.

Lyons, G.R. (1996). Learning disabilities. *Future of Children, 6*, 54-76.

Macan, T., Gibson, J. M., & Cunningham, J. (2010). Will you remember to read this article later when you have time? The relationship between prospective memory and time management. *Personality and Individual Differences 48*, 725–730

Mahy, C. E. V., & Moses, L. J. (2011). Executive functioning and prospective memory in young children. *Cognitive Development, 26*, 269–281.

Mahy, C. E. V., Moses, L. J., & Kliegel, M. (2014). The impact of age, ongoing task difficulty, and cue salience on preschoolers' prospective memory performance: The role of executive function. *Journal of Experimental Child Psychology.* http://dx.doi.org/10.1016/j.jecp.2014.01.006

Malm, J., Kristensen, B., Karlsson, T., Carlberg, B., Fagerlund, M., & Olsson, T. (1998). Cognitive impairment in young adults with infratentorial infarcts. *Neurology, 51*, 433-440.

Mantyla, T. (1994). Remembering to remember: Adult age-differences in prospective memory. *Journals of Gerontology, 49*, 276-282.

Mantyla, T. (2003). Assessing absentmindedness: Prospective memory complaint and impairment in middle-aged adults. *Memory & Cognition, 31*, 15-25.

Marsh, R. L., Cook, G. I., & Hicks, J. L. (2006). An analysis of prospective memory. In D. L. Medin (Ed.), *The psychology of learning and motivation* (Vol. 46, pp.115-153). Santiago, CA: Academic Press.

Marsh, R. L., Hancock, T.W., & Hicks, J. L. (2002). The demands of an ongoing activity influence the success of event-based prospective memory. *Psychonomic Bulletin and Review, 9*, 604–610.

Marsh, R. L., & Hicks, J. L. (1998). Event-based prospective memory and executive control of working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 336–349.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2006). Task interference from prospective memories covaries with contextual associations of fulfilling them. *Memory & Cognition, 34*, 1037–1045.

Marsh, R. L., Hicks, J. L., & Cook, G. I. (2008). On beginning to understand the role of context in prospective memory. In M. Kliegel, M. A. McDaniel, and G. O. Einstein (Eds.), Prospective Memory: Cognitive, Neuroscience, Developmental, and Applied Perspectives (pp. 77-100). Mahwah, NJ: Erlbaum.

Marsh, R. L., Hicks, J. L, Cook, G. I., Hansen, J. S., & Pallos, A. L. (2003). Interference to ongoing activities covaries with the characteristics of an event-based intention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(5), 861-870.

Martin, M., Kliegel, M., & McDaniel, M. A. (2003). The involvement of executive functions in prospective memory performance of adults. *International Journal of Psychology, 38*(4), 195-206.

Martin, M., & Schumann-Hengsteler, R. (2001). How task demands influence time-based prospective memory performance in young and older adults. *International Journal of Behavioural Development, 25,* 386-391.

Masumoto, K., Nishimura, C., & Tabuchi, M. (2011). What factors influence prospective memory for elderly people in a naturalistic setting? *Japanese Psychological Research, 53*(1), 30-41.

Maylor, E. A. (1993). Aging and forgetting in prospective and retrospective memory tasks. *Psychology and Aging, 8*, 420-428.

Maylor, E. A. (1995). Prospective memory in normal ageing and dementia. *Neurocase, 1,* 285-289.

Maylor, E. A. (1996). Age-related impairment in an event-based prospective-memory task. *Psychology and Aging, 11,* 74-78.

Maylor, E. A., Darby, R. J., Logie, R., Della Sala, S., & Smith, G. (2002). Prospective memory across the lifespan. In P. Graf & N. Otha (Eds.), *Lifespan development of human memory* (pp. 235-256). Cambridge: MIT Press.

McArthur, GM., & Bishop, D. (2001). Auditory perceptual processing in people with reading and oral language impairments: Current issues and recommendations. *Dyslexia, 7* (3), 150-170.

McBride, D. M., Beckner, J. K., & Abney, D. H. (2011). Effects of delay of prospective memory cues in an ongoing task on prospective memory task performance. *Memory & Cognition, 39,* 1222–1231.

McBride-Chang, C., & Manis, F. (1996). Structural invariance in the associations of naming speed, phonological awareness, and verbal reasoning in good and poor readers: A test of the double deficit hypothesis. *Reading and Writing, 8*, 323–339.

McCrory, E. J., Mechelli, A., Frith, U .and Price C. J. (2005). More than words: a common neural basis for reading and naming deficits in developmental dyslexia? *Brain, 128*, 261-267.

McDaniel, M. A., & Einstein, G. O. (1993). The importance of cue familiarity and distinctiveness in prospective memory. *Memory, 1*, 23-41.

McDaniel, M. A., & Einstein, G. O. (2000). Strategic and Automatic Processes in Prospective Memory Retrieval: A Multiprocess Perspective. *Applied Cognitive Psychology, 14,* 127-144.

McDaniel, M. A., & Einstein, G. O. (2007). *Prospective Memory: An Overview and Synthesis of an Emerging Field.* London: Sage Publications.

McDaniel, M. A., Einstein, G. O., & Rendell, P. G. (2008). The Puzzle of inconsistent age-related declines in prospective memory: A multiprocess explanation. In M. Kliegel, M. A. McDaniel, and G. O. Einstein (Eds.), *Prospective Memory: Cognitive, Neuroscience, Developmental, and Applied Perspectives* (pp. 141-160). Mahwah, NJ: Erlbaum.

McDaniel, M. A., Glisky, E. L., Rubin, S. R., Guynn, M. J., & Routhieaux, B. C. (1999). Prospective memory: A neuropsychological study. *Neuropsychology, 13*, 103–110.

McDaniel, M. A., Guynn, M. J., Einstein, G. O., & Breneiser, J. (2004). Cue-focused and reflexive-associative processes in prospective memory retrieval. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 605–614.

McDaniel, M. A., Lamontagne, P., Beck, S. M., Scullin, M. K., & Braver, T. S. (2013). Dissociable neural routes to successful prospective memory. *Psychological Society, 24*(9), 1791-1800.

McDaniel, M. A., Robinson-Riegler, B., & Einstein, G. O. (1998). Prospective remembering: Perceptually driven or conceptually driven processes? *Memory & Cognition*, *26,* 121–134.

McDougall, S. J., & Donohoe, R. (2002). Reading ability and memory span: Long-term memory contributions to span for good and poor readers. *Reading and Writing: An Interdisciplinary Journal , 15*, 359-387.

McFarland, C. P. & Glisky, E. L. (2009). Frontal lobe involvement in a task of time-based prospective memory. Neuropsychologia, 47, 1660-1669.

McLean, G.M.T., Stuart, G.W., Coltheart, V., & Castles, A. (2011). Visual Temporal Processing in Dyslexia and the Magnocellular Deficit Theory: The Need for Speed? *Journal of Experimental Psychology: Human Perception and Performance*, *37*(6), 1957–1975

McLeskey, J. (1980). Learning set acquisition: Problem solving strategies employed by reading disabled and normal children. *Journal of Learning Disabilities, 13,* 557–562.

McLoughlin, D., Fitzgibbon, G., & Young, V. (1994). *Adult dyslexia: Assessment, counselling and training.* London: Whurr.

McNamara, J. K., & Wong, B. (2003). Memory for Everyday Information in Students with Learning Disabilities. *Journal of learning disabilities, 36,* 394-406.

Meacham, J. A. & Leiman, B. (1982). Remembering to perform future actions. In U. Neisser (Ed.), *Memory observed: Remembering in natural contexts* (pp. 327-336). San Francisco: W. H. Freeman and Company.

Meacham, J. A., & Singer, J. (1977). Incentive effects in prospective remembering. *The Journal of Psychology, 97,* 191-197.

Miles, T. R. (1982). *The Bangor Dyslexia Test.* Cambridge: Learning Development Aids.

Miles, T. R. (1983). *Dyslexia: The pattern of difficulties.* London: Priory Press.

Miller, G. A., Galanter, E., & Pribram, K. H. (1960). *Plans and the structure of behavior.* New York: Holt, Rinehart & Winston.

Mioni, G., & Stablum, F. (2014). Monitoring behaviour in a time-based prospective memory task: The involvement of executive functions and time perception. *Memory*, *22*(5), 536-552.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49–100.

Montgomery, C., & Fisk, J. E. (2007). Everyday memory deficits in ecstasy-polydrug users. *Journal of Psychopharmacology, 21*(7), 709-717.

Moores, E., Nicolson, R. I., and Fawcett, A. J. (2002) Attentional deficits in dyslexia: Evidence for an automatisation deficit. *European Journal of Cognitive Psychology, 15,* 321-348.

Moretti, R., Bava, A., Torre, P., Antonello, R., & Gazzato, G. (2002). Reading errors in patients with cerebellar vermis lesions. *Journal of Neurology, 249,* 61–468.

Morgan, E. E., Weber, E., Rooney, A. S., Grant, I., Woods, S. P., & The HIV Neurobehavioral Research Program (HNRP) Group (2012). Longer ongoing task delay intervals exacerbate prospective memory deficits in HIV-associated neurocognitive disorders (HAND). *Journal of Clinical and Experimental Neuropsychology, 34*, 416–427.

Morgan, W. P. (1896). A Case of congenital word-blindness. *British Medical Journal, 2*, 1378.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behaviour, 16*, 519-533.

Morris, N., & Jones, D. M. (1990). Memory updating in working memory: The role of the central executive. *British Journal of Psychology, 81*, 111-121.

Morris, R. G., Evenden, J. L., Shakian, B. J., & Robbins, T. (1987). Computer-aided assessment of dementia: Comparative studies of neuropsychological deficits in Alzheimer-type dementia and Parkinson's disease. In S. M. Stahl & S. D. Iversen (Eds.), *Cognitive neurochemistry* (pp. 21-36). New York: Oxford University Press.

Moscovitch, M. (1982).Multiple dissociations of function in amnesia. In L. Cermak (Ed.), *Human memory and amnesia* (pp. 337-370). Hillsdale, NJ: Erlbaum.

Moscovitch, M. (1994). Memory and working with memory: Evaluation of a component process model and comparisons with other models. In D. L. Schacter & E. Tulving (Eds.), *Memory systems* (pp. 269–310). Cambridge, MA: MIT Press.

Muraven, M., Tice, D. M., & Baumeister, R. F. (1998). Self-control as a limited resource: Regulatory depletion patterns. *Journal of Personality and Social Psychology, 74*, 774–789.

Narhi, V., Rasanen, P., Metsapelto, R.-L., & Ahonen, T. (1997). Trail Making Test in assessing children with reading disabilities: A test of executive functions or content information. *Perceptual and Motor Skills, 84*, 1355–1362.

Nelson, H. E. (1982). A modified card sorting test sensitive to frontal lobe deficits. *Cortex. 12*, 313-324.

Nicolson, R. I., & Fawcett, A. J. (1990). Automaticity: a new framework for dyslexia research? *Cognition, 35*, 159-82.

Nicolson, R. I., & Fawcett, A. J. (1992). Spelling remediation for dyslexic children using the self-spell programs. *Lecture Notes in Computer Science, 602*, 503-515.

Nicolson, R. I., & Fawcett, A. J. (1994). Reaction times and dyslexia. *Q J Exp Psychol A, 47*(1), 29-48.

Nicolson, R. I., & Fawcett, A. J. (1997). Development of objective procedures for screening and assessment of dyslexic students in higher education. *Journal of Research in Reading, 20*(1), 7783.

Nicolson R. I., & Fawcett, A. J. (2008). Learning from the Science of Learning: Implications for the Classroom. *Dyslexia in Context: Research, Policy and Practice*, 257-277.

Nicolson, R. I., Fawcett, A. J., Berry, E. L., Jenkins, I. H., Dean, P., & Brooks, D. J. (1999). Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults. *Lancet*, *353*(9165), 1662-1667.

Nicolson, R. I., Fawcett, A. J., & Dean, P. (1995). Time estimation deficits in developmental dyslexia: evidence of cerebellar involvement. *Proceedings of the Royal Society of London Series B Biological Science, 259*, 43-7.

Nicolson, R. I., Fawcett, A. J., Berry, E. L., Jenkins, I. H., Dean, P., & Brooks, D. J. (1999) Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults. *The Lancet, 353*, 1662-166.

Nicolson, R. I., Fawcett, A. J., & Dean, P. (2001). Dyslexia, development and the cerebellum. *Trends Neuroscience, 24*, 515-6.

Nicolson, R. I., Fawcett, A. J., Moss, H., Nicolson, M. K., & Reason, R. (1999). Early reading intervention can be effective and cost-effective. *British Journal of Educational Psychology, 69*, 47-62.

Norman, D. A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (Vol. 4, pp. 1-8). New York: Plenum Press.

Okuda, J. T. (2007). Differential involvement of regions of rostral prefrontal cortex (Brodmann area 10) in time- and event-based prospective memory. *International Journal of Psychophysiology*, *64*(3), 233-246.

Okuda J., Fujii T., Ohtake H., Tsukiura T., Yamadori A., Frith C. D. (2007). Differential involvement of regions of rostral prefrontal cortex (Brodmann area 10) in time- and event-based prospective memory. *International Journal of Psychophysiology*, *64*(3), 233–246.

Olson, R., & Datta, H. (2002). Visual-temporal processing in reading-disabled and normal twins. Reading and Writing: *An Interdisciplinary Journal, 15*, 127-149.

Palladino, P., Cornoldi, C., De Beni, R., & Pazzaglia, F. (2001). Working memory and updating processes in reading comprehension. *Memory and Cognition*, *29*(2), 344-354.

Palladino, P., & Jarrold, C. (2008). Do updating tasks involve updating? Evidence from comparisons with immediate serial recall. *The Quarterly Journal of Experimental Psychology, 61*(3), 392–399.

Palmer, S. E. (2000). Phonological recoding deficit in working memory of dyslexic teenagers. *Journal of Research in Reading, 23*(1), 28-40.

Park, D. C., Hertzog, C., Kidder, D. P., Morrell, R. W., & Mayhorn, C. B. (1997). Effect of age on event-based and time-based prospective memory. *Psychology and Aging, 12*, 314-327.

Pearman, A. & Storandt, M. (2004). Predictors of subjective memory in older adults. *Journals of Gerontology: Psychological Sciences and Social Sciences, 59*, 4–6.

Pennekamp, P., Bosel, R., Mecklinger, A. & Ott, H. (1994). Differences in EEG theta for responded and omitted targets in a sustained attention task. *Journal of Psychophysiology*, *8*, 131–141.

Pennington, B. F., Gilger, J., Pauls, D., Smith, S. A., Smith, S. D., & DeFries, J.C. (1991). Evidence for major gene transmission of developmental dyslexia. *Journal of the American Medical Association*, *266*(11), 1527-1534.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathologies. *Journal of Child Psychology and Psychiatry Annual Research Review, 37*, 51-87.

Phillips, L. H., Henry, J. D. & Martin, M. (2008). Adult aging and prospective memory: the importance of ecological validity. (pp. 161-186). In Kliegel, M., McDaniel, M. A. & Einstein, G. O. (Eds.). *Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives.* Mahwah: Erlbaum.

Pickering, S.J., & Gathercole, S.E. (2005). Working memory deficits in dyslexia: are they located in the phonological loop, visuo-spatial sketchpad or central executive? In S. Gathercole & T. Alloway (Eds.). *Working Memory and Neurodevelopmental Disorders* (pp. 11-77), NY: Psychology Press.

Plaza, M., Cohen, H., & Chevrie-Muller, C. (2002). Oral Language Deficits in Dyslexic Children: Weaknesses in Working Memory and Verbal Planning. *Tennet XII* , 505-512.

Poliakoff, E., & Smith-Spark, J. H. (2008). Everyday cognitive failures and memory problems in Parkinson's patients without dementia. *Brain and Cognition, 67*, 340-350.

Poquette, A. J., Moore, D. J., Gouaux, B., Morgan, E. E., Grant, I., & Woods, S. (2013). Prospective memory and antiretroviral medication non-adherence in HIV: An analysis of ongoing task delay length using the Memory for Intentions Screening Test. *Journal Of The International Neuropsychological Society, 19*(2), 155-161.

Postle, B. R., Berger, J. S., Goldstein, J. H., Curtis, C.E., & D'Esposito, M. (2001). Behavioral and neurophysiological correlates of episodic coding, proactive interference, and list length effects in a running span verbal working memory task. *Cognitive, Affective, & Behavioral Neuroscience*, *1*(1), 10-21.

Equality Act 2010 (2010). Retrieved from http://www.legislation.gov.uk/ukpga/2010/15/pdfs/ukpga_20100015_en.pdf on the 14/03/2014.

Qualtrics software, Version 54548 of the Qualtrics Research Suite. Copyright © 2013 Qualtrics. Qualtrics and all other Qualtrics product or service names are registered trademarks or trademarks of Qualtrics, Provo, UT, USA. http://www.qualtrics.com

Rabbitt, P. (1997). Introduction: Methodologies and models in the study of executive function. In P. Rabbitt (Ed.), *Methodology of frontal and executive function* (pp. 1-38). Hove, UK: Psychology Press.

Rabbitt, P., Maylor, E., Mclnnes, L., Bent, N., & Moore, B. (1995). What goods can self assessment questionnaires deliver for cognitive gerontology? *Applied Cognitive Psychology, 9*, 127-152.

Rae, C., Lee, M. A., Dixon, R. M., Blamire, A. M., Thompson, C. H., Styles, P. et al. (1998). Metabolic abnormalities in developmental dyslexia detected by 1H magnetic resonance spectroscopy. *Lancet, 351*, 1849-52.

Ramus, F. (2003). Developmental dyslexia: specific phonological deficit or general sensorimotor dysfunction? *Current Opinion in Neurobiology , 13*, 212-218.

Ramus, F. (2004). Neurobiology of dyslexia: A reinterpretation of the data. *Trends in Neurosciences, 27*(12), 720-726.

Ramus, F., Marshall, C. R., Rosen, S., & van der Lely, H. K. (2013). Phonological deficits in specific language impairment and developmental dyslexia: towards a multidimensional model. *Brain*, *136*, 630–645.

Ramus, F., Rosen, S., Dakin, S. C., Day, B. L., Castellote, J. M., White, S. et al. (2003). Theories of developmental dyslexia: insights from a multiple case study of dyslexic adults. *Brain, 126*(4), 841-865.

Raskin, S. (2004). Memory For Intentions Screening Test (abstract). *Journal of the International Neuropsychological Society, 10* (Suppl. 1) 110.

Raskin, S. A., & Buckheit, C. (2001). Prospective memory functioning after brain injury (Abstract). *Journal of International Neuropsychological Society, 7* 249–250.

Raskin, S. A., Woods, S. P., Poquette, A. J., McTaggart, A. B., Sethna, J., Williams, R. C., & Tröster, A. I. (2011). A Differential Deficit in Time- versus Event-based Prospective Memory in Parkinson's Disease. *Neuropsychology, 25*(2), 201-209.Reason, J. T. (1983). Absent-mindedness and cognitive control. In J. E. Harris & P. E. Morris (Eds.), *Everyday memory: Actions and absent-mindedness* (pp. 113-132). London: Academic Press.

Reese, C. M., & Cherry, K. E. (2002). The effects of age, ability, and memory monitoring on prospective memory task performance. *Aging, Neuropsychology, and Cognition, 9,* 98–113.

Reid, G., Fawcett, A. J., Mains, F., & Siegel, L. (2008). *The Sage handbook of dyslexia, London: Sage.*

Reis, H. T. (2012). Why researchers should think “real-world”: A conceptual rationale. In M. R. Mehl, & T. S. Conner (Eds.), *Handbook of research methods for studying daily life* (pp. 585-600). New York, USA: The Guilford Press.

Reiter, A., Tucha, O., & Lange, K.W. (2005). Executive Functioning in Children with Dyslexia. Dyslexia, 11, 116-131.

Rendell, P. G., & Craik, F. I. M. (2000). Virtual week and actual week: Age-related differences in prospective memory. *Applied Cognitive Psychology, 14,* S43-S62.

Rendell, P. G., & Henry, J. D. (2008). Prospective-memory functioning is affected during pregnancy and postpartum. *Journal of Clinical and Experimental Neuropsychology, 30*(8), 913-919.

Rendell, P. G., McDaniel, M. A., Forbes, R. D., & Einstein, G. O. (2007). Age-related effects in prospective memory are modulated by ongoing task complexity and relation to target cue. *Aging, Neuropsychology, and Cognition, 14*, 236-256.

Rendell, P. G., & Thomson, D. M. (1993). The effect of aging on remembering to remember: An investigation of simulated medical regiments. *Australian Journal on Ageing, 12*(1), 11-18.

Rendell, P. G., & Thomson, D. M. (1999). Aging and prospective memory: Differences between naturalistic and laboratory tasks. *Journals of Gerontology Series B: Psychological Sciences and Social Sciences, 54*, 256–269.

Riddick, B., Sterling, S., Farmer, M. & Morgan, S. (1999). Self-esteem and anxiety in the educational histories of adult dyslexic students. *Dyslexia, 5,* 227–248.

Roberts, L. & McDougall, S. (2003). What do children do in the rime-analogy task? An examination of the skills and strategies used by early readers. *Journal of Experimental Child Psychology, 84,* 310-337.

Roche, N., Moody, A., Szabo, K., Fleming, J., & Shum, D. H. (2007). Prospective memory in adults with traumatic brain injury: An analysis of perceived reasons for remembering and forgetting. *Neuropsychological Rehabilitation, 17,* 314 –334.

Roediger, H. L. (1996). Prospective memory and episodic memory. In M. Brandimonte, G. Einstein, & M. McDaniel (Eds.), *Prospective memory: Theory and applications* (pp. 23-51). Hillsdale, NJ: Erlbaum.

Ronnlund, M., Mantyla, T., & Nilsson, L. (2008). The Prospective and Retrospective Memory Questionnaire (PRMQ): Factorial structure, relations to global subjective memory ratings, and Swedish norms. *Journal of Psychology, 49*, 11-18.

Roodenrys, S., & Stokes, J. (2001). Serial recall and nonword repitition in reading disabled children. *Reading and Writing: An Interdisciplinary Journal , 14*, 379-394.

Rummel, J., & Meiser, T. (2013). The role of metacognition in prospective memory: Anticipated task demands influence attention allocation strategies. *Consciousness and Cognition, 13*, 931–943.

Rutter, M. & Yule, W. (1975). The concept of specific reading retardation. *Journal of Learning Disabilities, 7,* 57-64.

Salthouse, T. A. (1984). Effects of age and skill in typing. *Journal of Experimental Psychology-General, 113*, 345–371.

Scaife, M., & Rogers, Y. (1996). External cognition: How do graphical representations work? *International Journal of Human-Computer Studies , 45*, 185-213.

Schmitter–Edgecombe, M., Woo, E., & Greeley, D. (2009). Characterizing multiple memory deficits and their relation to everyday functioning in individuals with mild cognitive impairment. *Neuropsychology, 23*, 168–177.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review, 84*, 1-66.

Schnitzspahn, K. M., Stahl, C., Zeintl, M., Kaller, C. P., & Kliegel, M. (2013). The role of shifting updating and inhibition in prospective memory performance in young and older adults. *Developmental Psychology, 49*, 1544-1553.

Schretlen, D., Pearlson, G. D., Anthony, J. C., Aylward, E. H., Augustine, A. M., Davis, A., & Barta, P. (2000). Elucidating the contributions of processing speed, executive ability, and frontal lobe volume to normal age-related differences in fluid intelligence. *Journal of the International Neuropsychological Society, 6,* 52-61.

Schwartz, S., Baldo, J., Graves, R. E., & Brugger, P. (2003). Pervasive influence of semantics in letter and category fluency: a multidimensional approach. *Brain Lang, 87*, 400–411.

Scullin, M. K., & Bugg, J. M. (2013). Failing to forget: Prospective memory commission errors can result from spontaneous retrieval and impaired executive control. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39,* 965–971.

Scullin, M. K., & McDaniel, M. A. (2010). Remembering to execute a goal: Sleep on it! *Psychological Science, 21*(7), 1028-1035.

Scullin, M. K., McDaniel, M. A., & Einstein, G. O. (2010). Control of cost in prospective memory: Evidence for spontaneous retrieval processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*, 190–203.

Scullin, M. K., McDaniel, M. A., Shelton, J. T., & Lee, J. H. (2010). Focal/Nonfocal Cue Effects in Prospective Memory: Monitoring Difficulty or Different Retrieval Processes? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 36*(3), 736-749.

Scullin, M. K., McDaniel, M. A., & Shelton, J. T. (2013). The Dynamic Multiprocess Framework: Evidence from prospective memory with contextual variability. *Cognitive Psychology, 67*, 55-71.

Sellen, A. J., Louie, G., Harris, J. E., & Wilkins, A. J. (1997). What brings intentions to mind? An in situ study of prospective memory. *Memory, 4*, 483-507.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, B, 298*, 199-209.

Shallice, T. (1988). *From neuropsychology to mental structure.* New York: Cambridge University Press.

Shallice, T., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain 114*, 727-741.

Shallice, T., & Burgess, P. W. (1993). Supervisory control of action and thought selection. In A. Baddeley & L. Weiskrantz (Eds.), *Attention: Selection, awareness, and control. A tribute to Donald Broadbent* (pp. 171-187). Oxford, UK: Oxford University Press.

Shaywitz, S. E. (1998). Current concepts of dyslexia. *The New England Journal of Medicine,* 338, 307-312.

Shum, D., Cross, B., Ford, R., & Ownsworth, T. (2008). A developmental investigation of prospective memory: Effects of interruption. *Child Neuropsychology, 14*, 547–561.

Singer, B. D., & Bashir, A. S. (1999). What are executive functions and self-regulation and what do they have to do with language-learning disorders? *Language, Speech, and Hearing Services in Schools, 30*, 265-273.

Smith, R. E. (2003). The cost of remembering to remember in event-based prospective memory: Investigating the capacity demands of delayed intention performance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 347-361.

Smith, R. E. (2008). *Connecting the past and the future.* In M. K. Kliegel, M. A. McDaniel, & G. O. Einstein (Eds.), Prospective memory: Cognitive, neuroscience, developmental, and applied perspectives. NJ: Lawrence Erlbaum Associate.

Smith, R. E., & Bayen, U. (2004). A multinomial model of prospective memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30,* 756-777.

Smith, G., Della Sala, S., Logie, R. H., & Maylor, E. A. (2000). Prospective and retrospective memory in normal ageing and dementia: A questionnaire study. *Memory, 8*(5), 311-321.

Smith, R. E., Hunt, R. R., McVay, J. C., & McConnell, M. D. (2007). The cost of event based prospective memory: Salient target events. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*, 734–746.

Smith, R: E., Persyn, D., & Butler, P. (2011). Prospective Memory, Personality, and Working Memory: A Formal Modeling Approach. *Zeitschrift für Psychologie / Journal of Psychology, 219*, 108-116.

Smith-Spark, J. H., Fawcett, A. J., Nicolson, R. I., & Fisk, J. E. (2004). Dyslexic students have more everyday cognitive lapses. *Memory*, *12*(2), 174-182.

Smith-Spark, J. H., & Fisk, J. E. (2007). Working memory functioning in developmental dyslexia. *Memory, 15 (1)*, 34-56.

Smith-Spark, J.H., Fisk, J.E., Fawcett, A.J. & Nicolson, R.I. (2003). Investigating the central executive in adult dyslexics: Evidence from phonological and visuospatial working memory performance. *European Journal of Cognitive Psychology, 15* (4), 567-587.

Snodgrass, J.G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174-215.

Snowling, M. J. (1981). Phonemic deficits in developmental dyslexia. *Psychological Research, 43*, 219-234.

Snowling, M. J. (1995) Phonological processing and developmental dyslexia. *Journal of Research in Reading, 18*, 132-138.

Snowling, M. J. (2000). *Dyslexia* (2nd ed.). Oxford: Blackwell.

Snyder, L. S., & Downey, D. M. (1995). Serial rapid naming skills in children with reading disabilities. *Annals of Dyslexia, 45,* 31-47.

Stanovich, K. E. (1988a). The right and wrong places to look for the cognitive locus of reading disability. *Annals of Dyslexia, 38,* 154-177.

Stanovich, K. E. (1988b). Explaining the differences between the dyslexic and the garden-variety poor reader: the phonological-core variable-difference model. *Journal of Learning Disabilities, 22,* 366-369.

Stanovich, K. E., & Siegel, L. S. (1994). Phenotypic performance profile of children with reading disabilities: A regression-based test of the phonological-core variable-difference model. *Journal of Educational Psychology, 86*, 24-53.

Stein, J. (2001). The magnocellular theory of developmental dyslexia. *Dyslexia 7,* 12–36.

Stein, J., & Talcott, J. (1999). Impaired neuronal timing in developmental dyslexia: The magnocellular hypothesis. *Dyslexia, 5,* 59–77.

Stein, J., & Walsh, V. (1997). To see but not to read; the magnocellular theory of dyslexia. *Trends in Neurosciences, 20*(4), 147-152.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of experimental Psychology, 18,* 643-662.

Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. *Psychological Bulletin, 95,* 3–28.

Sunderland, A. (1990). Clinical Memory Assessment: Matching the Method to the Aim. In D. E. Tupper, & K. D. Cicerone (Eds.), *The Neuropsychology of Everyday Life: Assessment and Basic Competencies Foundations of Neuropsychology* (Vol. 2, pp. 169-183). Boston: Kluwer Academic Publishers.

Swanson, H. L. (1994) Short-term memory and working memory: Do they both contribute to our understanding of academic achievement in children and adults with learning disabilities? *Journal of Learning Disabilities, 27,* 34-50.

Swanson, H. L. (1999). Reading comprehension and working memory in language-disabled readers: Is the phonological loop more important than the executive system? *Journal of Experimental Child Psychology, 72,* 1-31.

Swanson. H. L. (2006). Working memory and reading disabilities: Both phonological and executive processing deficits are important. In T. P. Alloway & S. E. Gathercole (Eds.), *Working memory and neurodevelopmental disorders* (pp. 59-83). Hove: Psychology Press.

Talcott, J., Hansen, P., Assoku, E. & Stein, J. (2000). Visual motion sensitivity in dyslexia: Evidence for temporal and energy integration deficits. *Neuropsychologia,* 38, 935-943.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. *Brain and Language, 9*, 182-198.

Tallal, P. (1985). Auditory temporal perception, phonics and reading disabilities in children. *Brain & Language*, *9,* 182-198.

Tallal, P., Miller, S., Bedi, G., Byma, G., Wang, X., Nagarajan, S., Schreiner, C., Jenkins, W. M., & Merzenich, M. M. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science, 271*, 81–84.

Tallal, P., Miller, S., & Fitch, R. H. (1993). Neurobiological basis of speech: A case for the preeminence of temporal processing. *Annals of the New York Academy of Sciences, 682*, 27-47.

Tallal, P., Miler, S. L., Jenkins, W. M. & Merzenich, M. M. (1997). The role of temporal processing in developmental language-based learning disorders: Research and clinical Implications. In B. A. Blachman (Ed.), *Foundations of reading acquisition and dyslexia: Implications for early intervention* (pp. 49–66). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Tallal, P., & Piercy, M. (1973). Defects of non-verbal auditory perception in children with developmental aphasia. *Nature, 241,* 468-469.

Thorndike, E. L. (1914). *The psychology of learning.* New York: Teachers College.

Tobias, R. (2009). Changing behavior by memory aids: a social psychological model of prospective memory and habit development tested with dynamic field data. *Psychol Rev. 116*(2), 408-438.

Torgesen, J. K. (1977). The role of nonspecific factors in the task performance of learning disabled children: A theoretical assessment. *Child Development, 48,* 56-60.

Torgesen, J. K., Wagner, R. K., Rashotte, C. A., Burgess, S. R., & Hecht, S. A. (1997). Contributions of phonological awareness and rapid autonomic naming ability to the growth of word-reading skills in second- to fifth-grade children. *Scientific Study of Reading, 2,* 161-185.

Turner, M. (1997). *Psychological assessment of dyslexia.* London: Whurr.

Uttl, B. (2008). Transparent Meta-Analysis of Prospective Memory and Aging. *PLoS ONE 3*(2): e1568. doi: 10.1371/journal.pone.0001568

Uttl, B., & Kibreab., M. (2011). Self-report measures of prospective memory are reliable but not valid. *Canadian Journal of Experimental Psychology 65* (1), 57-68.

Van den Berg, S.M., Aarts, H., Midden, C. & Verplanken, B. (2004). The role of executive processes in prospective memory tasks. *European Journal of Cognitive Psychology, 16*, 511-533.

Van den Bos, K. P. (1998). IQ, phonological awareness and continuous-naming speed related to Dutch poor decoding children’s performance on two word identification tests. *Dyslexia, 4,* 73-89.

Varvara, P., Varuzza, C., Sorrentino, A. C. O., Vicari, S., Menghini, D. (2014). Executive functions in developmental dyslexia. *Frontiers in Human Neuroscience, 8*(120), 1662-5161.

Vellutino, F. R. (1979). *Dyslexia: Research and Theory*. Cambridge, MA: MIT Press.

Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific Reading Disability (Dyslexia): What have we learned in the past four decades? *Journal of Child Psychology & Psychiatry, 45,* 2-40.

Vellutino, F. R., & Scanlon, D. M. (1987). Phonological coding, phonological awareness, and reading ability: Evidence from a longitudinal and experimental study. *Merril-Palmer Quarterly Journal of Developmental Psychology, 33*(3), 321-363.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin, 101*(2), 192-212.

Wagner, R. K., Torgesen, J. K., Laughon, P., Simmons, K., & Rashotte, C. A. (1993). The development of young readers’ phonological processing abilities. *Journal of Educational Psychology, 85,* 1-20.

Ward, H., Shum, D., McKinlay, L., Baker-Tweney, S., & Wallace, G. (2005). Development of prospective memory: Tasks based on the prefrontal-lobe model. *Child Neuropsychology, 11*, 527–549.

Wechsler, D. (1993). *The Wechsler Objective Reading Dimensions*. London: The Psychological Corporation.

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale (4th ed.)*. San Antonio, TX: The Psychological Corporation.

Wecker, N. S., Kramer, J. H., Wisniewski, A., Delis, D. C., & Kaplan, E. (2000). Age effects on executive ability. *Neuropsychology, 14,* 409-414.

Weinborn, M., Paul Woods, S., Nulsen, C., & Park, K. (2011). Prospective memory deficits in Ecstasy users: Effects of longer ongoing task delay interval. *Journal of clinical and experimental neuropsychology, 33*(10), 1119-1128.

Welsh, M., Pennington, B., & Graisser, D. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology, 7,* 131-149.

Wentland, E. J., & Smith, K. W. (1993). *Survey responses: An evaluation of their validity.* New York: Academic Press.

West, R., Carlson, L., & Cohen, A-L. (2007). What the eyes can tell us about prospective memory. *The International Journal of Psychophysiology, 64,* 269-277.

West, R., Bowry, R., & Krompinger, J. (2005). The effects of working memory demands on the neural correlates of prospective memory. *Neuropsychologia, 44,* 197-207.

West, R., Herndon, R. W., Ross-Munroe, K. (2000). Event-related neural activity associated with prospective remembering. *Applied Cognitive Psychology, 14*, 115–126.

West, R., Herndon, R. W., Crewdson, S. J. (2001). Neural activity associated with the realization of a delayed intention. *Cognitive Brain Research 12*, 1–10.

West, R. L., McNerney, M. W., & Krauss, I. (2007). Impaired Strategic Monitoring as the Locus of a Focal Prospective Memory Deficit. *Neurocase, 13,* 115-126.

Weyandt, L. L., Rice, J. A., Linterman, I., Mitzlaff, L., & Emert, E. (1998). Neuropsychological performance of a sample of adults with ADHD, developmental reading disorder, and controls. *Developmental Neuropsychology, 14,* 643–656.

Wilson, B. A., Cockburn, J., & Baddeley, A. D. (1985). *The Rivermead Behavioral Memory Test*. Titchfield, UK: Thames Valley Test Co.

Winograd, E. (1988). *Some observations on prospective remembering*. In M. M. Gruneberg, P. E. Morris & R. N. Sykes (Eds.), Practical Aspects of Memory: Current Research and Issues (Vol. 2, pp. 348–353). Chichester: Wiley.

Witton, C., Talcott, J. B., Stoodley, C. J., & Stein, J. F. (2000). Frequency modulation, amplitude modulation and phonological ability in developmental dyslexia. *British Journal of Audiology, 34*(2), 123-124.

Wolf, M., & Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexia. *Journal of Educational Psychology, 91*(3), 415–438.

Wolf. M., & Bowers, P. (2000) Naming-Speed Processes and Developmental Reading Disabilities: An Introduction to the Special Issue on the Double-Deficit Hypothesis. *Journal of Learning Disabilities*, *33*, 322-324

Woods, S. P., Dawson, M. S., Weber, E., Gibson, S., Grant, I., Atkinson, J. H. (2009). Timing is everything: antiretroviral nonadherence is associated with impairment in time-based prospective memory. *Journal of the International Neuropsychological Society*, *15*, 42 52.

Woods, S.P., Moran, L. M., Dawson, M. S., Carey, C. L., Grant, I., & The HIV Neurobehavioral Research Center (HNRC) Group (2008). Psychometric characteristics of the memory for intentions screening test. *The Clinical Neuropsychologist 22*, 864–878.

Woods, S. P., Twamley, E. W., Dawson, M. S., Narvaez, J. M., & Jeste, D. V. (2007). Deficits in cue detection and intention retrieval underlie prospective memory impairment in schizophrenia. *Schizophrenia Research 90* (1-3), 344-350.

Zahednezhada, H., Poursharifib, H., & Babapourb, J. (2011). Memory, health locus of control and adherence in type II diabetic patients in Iran – Tabriz. *Procedia - Social and Behavioral Sciences 30*, 2621 – 2624.

Appendices:

Appendix 1: Stimuli list for focal (Study 4) and non-focal (Study 5) experiments

FOCAL			
BLOCK 1		BLOCK 2	
LIVING	NON-LIVING	LIVING	NON-LIVING
Nose	Belt	Pear	Bowl
Apple	Frying Pan	Banana	Glass
Lips	Scissors	Cherry	Button
Tomato	Refrigerator	Lemon	Ironing Board
Toe	Plug	Orange	Garbage Can
Foot	Rugby Ball (Football)	Arm	Fork
Finger	Comb	Potato	Doorknob
Leaf	Broom	Leg	Toaster
Hand	Vest	Ear	Glasses
Grapes	Lightbulb	Carrot	Tie
Cat	Umbrella	Eye	Saltcellar (Saltshaker)
Horse	Shirt	Corn	Iron
Celery	Television	Squirrel	Telephone
NON-FOCAL			
BLOCK 1		BLOCK 2	
LIVING	NON-LIVING	LIVING	NON-LIVING
Pear	Key	Lips	Refrigerator
Lemon	Belt	Finger	Plug
Cherry	Frying Pan	Banana	Ladder
Apple	Scissors	Nose	Envelope
Tomato	Pliers	Orange	Sock
Toe	Rugby Ball (Football)	Arm	Button
Foot	Comb	Thumb	Ironing Board
Potato	Broom	Leaf	Screwdriver
Carrot	Umbrella	Leg	Light Switch
Hand	Shirt	Ear	Fork
Grapes	Baseball bat	Corn	Toaster
Cat	Glass	Squirrel	Television
Celery	Telephone	Horse	Iron

Appendix 2: Stimuli Matching using one-way ANOVA

	Focal						Non-focal					
	Living B1 vs. B2		Non-Living B1 vs. B2		All B1 vs. B2		Living B1 vs. B2		Non-Living B1 vs. B2		All B1 vs. B2	
Variable	*F* (1, 24)	*p*	*F* (1, 24)	*p*	*F* (1, 50)	*p*	*F* (1, 24)	*p*	*F* (1, 24)	*p*	*F* (1, 50)	*p*
Image Agreement	1.284	.268	1.022	.322	2.355	.131	.586	.452	.097	.758	.601	.442
Familiarity Ratings	2.576	.122	.023	.880	1.335	.253	2.410	.134	.006	.939	1.116	.296
Visual Complexity	.254	.619	.386	.540	.017	.895	.119	.733	.042	.839	.165	.686
Black Pixels (%)	.152	.700	.187	.669	.002	.966	.848	.328	.082	.777	.880	.353
Area of Drawing	.276	.604	.488	.492	.721	.400	3.236	.085	1.132	.298	< .001	.987

Note: B = Block; All = living + non-living

Appendix 3: Trimmed data analysis - event-based: Focal design

3.1. Data trimming procedure

The accuracy and RT data were analysed after trimming. The trimming followed similar principles to those used in other peer review published investigations looking at prospective memory. Namely, the first six trials from both Block 1 and Block 2 were removed (regardless of whether the responses to these trials were correct of incorrect). This was performed similarly to Smith, Persyn, and Butler (2011). Two trials (again regardless whether these were correct or incorrect) appearing straight after each of the 8 PM cues were removed in Block 2 (e.g. Loft, Pearcy & Remington, 2011; Smith, Hunt, McVay & McConnell, 2007). Breneiser (2009) stated that removal of the two trials occurring after PM cue is needed as the appearance of PM cue could interrupt processing of the onging task. This in turn could produce ongoing trials which are not characteristic of a participant's true performance. Consistent with, Cohen, Judas, and Gollwitzer (2008) all of the ongoing trial latencies (correct only) which were less than 300ms or more than three standard deviations from the cell mean were disregarded.

3.2. Trimmed accuracy and RT data

The accuracy and RT data were trimmed for this analysis. This data trimming process performed on the ongoing responses removed 18.55% of the total correct ongoing responses across the two blocks (16.98% of all of the responses provided in the experiment including PM trials). All of the results acquired from the data after they were trimmed are presented in Table 32. The same tests were used to analyse the trimmed data as were previously performed on the non-trimmed data. Namely, Table 32 includes means, one-way ANOVA on PM trials and mixed measures ANOVA looking at the cost of performing PM task on the ongoing trials in Block 2 compared to Block 1.

Table 32: Means and mixed measures ANOVA using accuracy and RT data.

Means	Accuracy (%)				RT (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	95.52	5.68	97.31	3.15	1758.49	419.51	2469.14	958.00
Ongoing (Block 2)	96.29	7.81	97.47	2.85	1802.46	348.73	2507.44	926.16
PM (Block 2)	83.33	27.25	81.25	30.26	1300.46	327.33	1681.78	670.76

Mixed measures ANOVA ***Ongoing trials (Block 1 and Block 2)***	Accuracy (%)			RT (ms)		
	F (1, 48)	p	η_p^2	F (1, 48)	p	η_p^2
Group	1.405	.242	.028	12.631	.001	.208
Block	.365	.549	.008	.546	.463	.011
Group * Block interaction	.157	.693	.003	.003	.960	< .001

The results from one-way ANOVA remained the same as no PM trials were removed. The results from the mixed measures ANOVA performed on the trimmed data were similar to the results acquired from the non-trimmed data. There was a significant main effect of participant group in the RT data. However, the analysis performed on the trimmed RT data did not produce an effect of block approaching significance as it was observed in the non-trimmed data (nonetheless, they are both non-significant).

Appendix 4: Trimmed data analysis - event-based Non-focal experiment

4.1. Data trimming procedure

The same data trimming procedure as used in the focal experiment was applied to this analysis. Data trimming process performed on the ongoing responses removed 18.87% of the total correct ongoing responses across the two blocks (18.12% of all of the responses provided in the experiment including PM trials). All of the results acquired from the data after they were trimmed are presented in Table 33. The same tests were used to analyse the trimmed data as were performed on the non-trimmed data. Table 33 includes means, one-way ANOVA on the two tasks (ongoing and PM) across the two blocks and mixed measures ANOVA looking at the cost of performing PM task on the ongoing trials in Block 2 compared to Block 1.

4.2. Trimmed accuracy and RT data

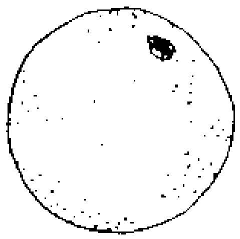
Table 33: Means and mixed measures ANOVA using accuracy and RT data.

Means	Accuracy (%)				RT (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	96.75	3.21	96.27	4.15	1428.30	486.97	2007.29	852.21
Ongoing (Block 2)	96.12	3.09	95.16	7.59	1492.79	398.40	2215.78	973.14
PM (Block 2)	77.84	24.68	71.43	28.82	1137.51	359.95	1431.13	568.44

Mixed measures ANOVA ***Ongoing trials (Block 1 and Block 2)***	Accuracy (%)			RT (ms)		
	F (1, 41)	p	η_p^2	F (1, 41)	p	η_p^2
Group	.427	.517	.010	10.211	.003	.199
Block	.773	.384	.019	5.130	.029	.111
Group * Block interaction	.058	.811	.001	1.052	.311	.025

The results from the one-way ANOVA remained the same as no PM trials were removed. The results from the mixed measures ANOVA performed on the trimmed data were similar to the results acquired from the non-trimmed data. There were significant main effects of participant group and block type in the RT data, but the interaction between the two was not significant. The two effects and their interaction were not significant for the accuracy data.

Appendix 5: Stimuli used as PM targets in non-focal experiment



Appendix 6: Juxtaposition of tables displaying means from focal and non-focal experiments based on non-trimmed data

FOCAL	Accuracy (%)				Reaction time (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	95.05	5.62	96.73	3.18	1804.80	435.23	2552.25	972.64
Ongoing + PM (Block 2)	94.32	8.41	96.06	3.75	1829.13	327.90	2607.30	906.07
Ongoing (Block 2)	95.54	8.71	97.70	2.19	1885.92	353.21	2696.92	951.96
PM (Block 2)	83.33	27.25	81.25	30.26	1260.89	361.94	1652.84	679.32

NON-FOCAL	Accuracy (%)				Reaction time (ms)			
	Controls		Dyslexics		Controls		Dyslexics	
Type of Trial	*M*	SD	*M*	SD	*M*	SD	*M*	SD
Ongoing (Block 1)	96.59	3.25	96.07	4.17	1469.40	454.15	2113.64	897.80
Ongoing + PM (Block 2)	93.98	4.15	93.10	6.84	1548.59	387.08	2257.29	902.46
Ongoing (Block 2)	95.77	3.85	95.50	6.50	1586.67	403.17	2323.68	937.98
PM (Block 2)	77.84	24.68	71.43	28.82	1137.51	359.95	1431.13	568.44

Appendix 7: Stimuli list used in Time-based experiments.

LIVING	DEAD
Barrack Obama	Albert Einstein
Beyonce	Amy Winehouse
Brad Pitt	Bob Marley
David Beckham	Elvis Presley
George Clooney	Freddie Mercury
Johnny Depp	Heath Ledger
Justin Beiber	John Lennon
Kate Middleton	Kurt Cobain
Madona	Marilyn Monroe
Rhianna	Michael Jackson
Simon Cowell	Princess Diana
The Queen	Whitney Huston
Barrack Obama	Albert Einstein

Appendix 8: Naturalistic Study Instructions (event-based)

You will receive a text message (SMS) one week after today. In this message only your initials and participant number will appear. You are requested to remember to call the experimenter as soon as possible (preferably within 5 minutes) using the number from which the text message was sent. When placing the call, please wait for the phone to ring once and then end the call. Please note that the researcher will not answer the call so it will not cost you any money.

Please do NOT use external reminders such as sticky notes or calendar entries to remind you to return the call.

Once you have read through these instructions, please explain to the experimenter what you are asked to do.

Do you fully understand the instructions to respond as soon as possible (preferably within 5 min) to text messages sent by the experimenter, by dialing the number that the text message with your initials and participant number was received from and ending the call when you hear the phone ring once?

Yes / No

Mobile Phone Usage

You are asked a few questions with regards to your mobile phone. The reason for this is to prevent a situation where you cannot respond to the text messages sent by the researcher due to insufficient funds on your phone (e.g. where your outgoing calls are bared).

1. Do you own a mobile phone? If yes, what is your mobile phone number that you use the most? …………………………..

2. Is this phone a Contract phone or a Pay as You Go phone?

   Contract / Pay as You Go

3. Do you give consent to the experimenter to contact you on this number?

   Yes/No

4. If your phone is a Pay as You Go, are there long periods of time that you have no money on your phone to make phone calls?

   Yes / No

5. How competent are you in using your mobile phone to make missed calls (in which you end the call after the phone you are dialling rings once)?

   (1 being not at all and 10 being extremely competent)

   1 2 3 4 5 6 7 8 9 10

6. How competent are you in using mobile your phone to receive text messages (SMS)?

   (1 being not at all and 10 being extremely competent)

   1 2 3 4 5 6 7 8 9 10

7. How competent are you in using your mobile phone to make a voice call to the sender of a text message (SMS) that you receive?

(1 being not at all and 10 being extremely competent)

1 2 3 4 5 6 7 8 9 10

8. Please provide an estimate of how often you check your mobile phone? (if you have more than one mobile phone numbers, provide an estimate for the number you have given to the researcher)

More than 10 times a day

Between 5 and 10 times a day

Between 2 and 4 times a day

Once a day

Once every few days

Once a week

Appendix 9: Follow up email

1. Did you receive the text message (SMS) from the experimenter one week after the experiment?

Yes / No (**Bold** the answer)

2. Did you remember the instruction requesting you to respond to the text message (SMS) by using the number from the text message; waiting for the phone to ring once and end the call?

Yes / No

3. How much importance did you place on the activity of responding to the text message by calling the sender's number?

(1 being none and 10 being extremely important)

1 2 3 4 5 6 7 8 9 10

4. If you responded to the text message later than 5 minutes after receiving it, what was the reason for this?

I had forgotten to do it /
I was busy /
I have not checked my mobile phone for quite a while /
I was on the phone or received many other more important text messages that needed to be responded to /
Other, please state….…

5. In the time interval between leaving my experiment and receiving my text message (SMS), please estimate how many times you thought about responding to this email by placing a missed call to the experimenter?

More than 20 times

Between 15 and 20 times

Between 10 and 14 times

Between 5 and 9 times

Between 3 and 4 times

Two times

Once

I did not think about it at all until I received the text message

Appendix 10: Naturalistic Study Instructions (time-based)

You are asked to send a text message with your name and surname to the researcher in one week from now. Please send the text message on …………………………at ……………(preferably within 5 minutes from that time).

Please **do NOT** use external reminders such as sticky notes or calendar entries to remind you to send the text message to the researcher.

The number to text is **07748825127**. Please save the phone number in your phone, but not as a reminder note.

Once you have read through these instructions, please explain to the experimenter what you are asked to do.

Questions

1. Do you fully understand the instructions to send a text message with your name and surname to the experimenter in one week from now?

   Yes / No

2. Please indicate on the scale below how motivated you are to send the text message (SMS) to the researcher.

   (1 being not motivated at all and 10 extremely motivated)

   1 2 3 4 5 6 7 8 9 10

3. How likely do you think it is that you will remember to send the text message to the researcher?

(1 being not likely at all and 10 extremely likely)

1 2 3 4 5 6 7 8 9 10

Mobile Phone Usage

You are asked a few questions with regards to your mobile phone. The reason for this is to prevent a situation where you cannot send the text messages due to insufficient funds on your phone (e.g. where your outgoing messages are bared).

9. Do you own a mobile phone? If yes, what is your mobile phone number that you use the most? …………………………..

10. Is this phone a Contract phone or a Pay as You Go phone?

Contract / Pay as You Go

11. If your phone is a Pay as You Go, are there long periods of time that you have no money on your phone to make phone calls?

Yes / No

12. How competent are you in using mobile your phone to send text messages (SMS)?

(1 being not at all and 10 being extremely competent)

1 2 3 4 5 6 7 8 9 10