Running Head: PROSPECTIVE MEMORY IN DYSLEXIA

Adults with developmental dyslexia show selective impairments in time-based and self-initiated prospective memory: Self-report and clinical evidence

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Abstract

Background: Prospective memory (PM; memory for delayed intentions) would seem to be impaired in dyslexia but evidence is currently limited in scope. Aims: There is a need, therefore, firstly, to explore PM under controlled conditions using a broader range of PM tasks than used previously and, secondly, to determine whether objectively measured and self-reported PM problems can be found in the same individuals with dyslexia. Methods and Procedures: The responses of 30 adults with dyslexia were compared with those of 30 IQ-matched adults without dyslexia on a self-report and a clinical measure of PM. Outcomes and Results: Dyslexia-related deficits were shown on the clinical measure overall and, more particularly, when PM responses had to be made to cues based on time rather than environmental events. Adults with dyslexia were also more likely to forget to carry out an intention under naturalistic conditions 24 hours later. On the self-report questionnaire, the group with dyslexia reported significantly more frequent problems with PM overall, despite using more techniques to aid their memory. In particular, problems were identified with longer-term PM tasks and PM which had to be self-initiated. Conclusions and Implications: Dyslexia-related PM deficits were found under both laboratory and everyday conditions in the same participants; the first time that this has been demonstrated. These findings support previous experimental research which has highlighted dyslexia-related deficits in PM when the enacting of intentions is based on time cues and/or has to be self-initiated rather than being in prompted by environmental events.

Keywords: dyslexia; adults; prospective memory; Prospective Memory Questionnaire; Memory for Intentions Test

What this paper adds

Prospective memory (PM; memory for delayed intentions) seems to be impaired in individuals with dyslexia but the evidence is currently limited. Experimental data from adults have shown dyslexia-related problems with PM but, since only time cues were used, it cannot be determined whether difficulties are specific to time-based PM or part of a more general deficit. Moreover, whilst self-reports of increased PM failure in dyslexia have also been found, it has not yet been established whether the self-reported deficits of people with dyslexia are reflected in the objectively measured PM performance of the same individuals. A self-report questionnaire and a clinical measure of PM were, therefore, administered to the same sample of adults with and without dyslexia. On the clinical measure, the PM performance of the group with dyslexia was worse overall and displayed particular difficulties when time cues were used. On the questionnaire, a greater overall frequency of PM failure in dyslexia was also self-reported. More specifically, adults with dyslexia identified problems with long-term, one-off PM tasks and those which required self-initiated remembering. Both the clinical test and the self-report questionnaire indicate that PM is impaired in dyslexia. A theme common to both measures was that performance relying on cues based on time or needing to be self-initiated appears to be adversely affected by dyslexia whilst performance in response to external cues seems unaffected. The findings suggest that specific areas of PM are affected by dyslexia. Future research should explore the cognitive mechanisms responsible for impairments and for identifying where support is needed for individuals with the condition.

Adults with developmental dyslexia show selective impairments in time-based and self-initiated prospective memory: Self-report and clinical evidence

1. Introduction

Developmental dyslexia (henceforth, dyslexia) is typically characterized by persistent problems with reading or spelling, or both (Lyon, Shaywitz & Shaywitz, 2003; Siegel, 2006). These difficulties have been seen as part of a wider impairment in phonological processing (e.g., Castles & Friedmann, 2014; Vellutino, Fletcher, Snowling & Scanlon, 2004). However, as well as affecting reading and spelling, the presence of dyslexia has also been found to have adverse effects on both short-term and working memory (e.g., Jorm, 1983; Palmer, 2000; Smith-Spark, Fisk, Fawcett & Nicolson, 2003; Swanson, 1992, 1999). Whilst these problems are well-documented, the function of other memory systems in dyslexia has received considerably less scrutiny. The focus of the current paper was on prospective memory (PM), also known as memory for delayed intentions (e.g., Winograd, 1988). Successful PM allows individuals to defer to an appropriate point in the future a range of day-to-day activities such as returning telephone calls, posting letters, buying groceries, meeting work colleagues or friends, taking regular medication, and paying bills. Despite the importance of this memory system to everyday life, there is currently only a small body of research on PM in dyslexia. Self-report evidence has indicated that individuals with dyslexia consider themselves to experience more frequent failures of PM on a day-to-day basis (Khan, 2014; Smith-Spark, Zięcik & Sterling, 2016a). Lowered PM accuracy has also been found in adults with dyslexia on a laboratory-based task (Smith-Spark, Zięcik & Sterling, 2016b). However, this is the extent of the direct literature on PM in dyslexia to date. In order to gain a more comprehensive understanding of the effects of dyslexia on PM, a clinical measure of PM (the Memory for Intentions Test; MIST; Raskin, Buckheit & Sherrod,

2010) was administered in the current paper. This has a number of scales designed to tap into a broader range of aspects of PM than previously explored in dyslexia. Self-reported deficits were also probed in more depth than previously, using a questionnaire dedicated entirely to PM (the Prospective Memory Questionnaire; PMQ; Hannon et al., 1995). The present paper would thus shed light on whether PM difficulties could be identified in the same group of adults with dyslexia both under laboratory and everyday conditions. Such wide-ranging evidence in terms of both methodological approach and granularity of measurement would contribute substantially to an evidence base on which to argue for appropriate support for adults with dyslexia in both education and employment.

Stanovich (2009) presents a framework for cognition within which different levels are considered. The reflective level of cognition is argued to relate to goals, beliefs about those goals, and the choice of which action to take in order to fit best with these goals and beliefs. Given that the reflective level deals with typical, everyday performance, it is likely to be measured most effectively by self-reports of general performance over a protracted timeframe. The algorithmic level of Stanovich's scheme, on the other hand, corresponds to information processing mechanisms and is usually tapped by performance measures under laboratory conditions where optimal performance is required. To understand cognition under both typical and optimal conditions (e.g., Topiak, West & Stanovich, 2013), both the reflective and algorithmic levels need to be studied. The study of PM is no different from any other area of cognition in this regard and, given the importance of PM to successful everyday function (e.g., McDaniel & Einstein, 2007), investigating both typical and optimal performance is even more necessary to understanding the range of difficulties experienced by people with dyslexia.

Two key cognitive components (e.g., Einstein & McDaniel, 1990, 1996) are required for PM to act effectively. The role of the prospective (or planning) component is to ensure that the intended behaviour is recalled at the appropriate point in the future. The retrospective component is responsible for making sure that the individual remembers the contents of the intention itself. Beyond this distinction, PM tasks can be either event-based (EBPM) or time-based (TBPM) in nature (e.g., McDaniel & Einstein, 2007). In the case of EBPM, an individual is required to respond to an event in the environment in order to perform the intended action; for example, seeing a colleague should act as a trigger to remember the intention to pass on a message to her. With EBPM, cues in the environment are able to "pop" out at the individual and remind him or her to perform the delayed intention. Time-based PM requires an individual to perform an intended action at a particular time in the future; for example, remembering to telephone a colleague for a discussion in 30 minutes' time. It has been argued that self-initiated mental processes are drawn upon more heavily when TBPM is required than when EBPM is needed (e.g., Einstein, McDaniel, Richardson, Guynn & Cunfer, 1995). In the former case, the individual has to engage in more strategic, self-generated processes (such as free recall) to guide performance.

As stated previously, self-report data (Khan, 2014) have suggested that PM is impaired in dyslexia. In Khan's (2014) study, children with dyslexia reported a greater frequency of PM (as well as retrospective memory) failure in response to the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie & Maylor, 2000). Smith-Spark et al. (2016a) have administered the PRMQ to adults with and without dyslexia. They found similar reports of heightened frequencies of memory error across both the PM and retrospective memory scales. These self-reports were corroborated by close associates who completed a parallel proxy-rating version of the PRMQ (Crawford, Henry, Ward & Blake, 2006) and, likewise, reported higher frequencies of memory failure in the adults with dyslexia.

Further to the self-report data indicating a greater frequency of PM problems in dyslexia (Khan, 2014; Smith-Spark et al., 2016a), one study of optimal, laboratory-based PM performance in dyslexia has been reported to date. Smith-Spark et al. (2016b) used a computerized task to uncover less accurate TBPM performance in adults with dyslexia compared with a short-form IQ matched group of adults without dyslexia. The group with dyslexia were significantly less accurate overall in their PM responses and also made fewer clock checks to guide their performance. Smith-Spark et al. varied the cognitive load associated with the ongoing task but did not find a differential effect of increased working memory load on the PM performance of the group with dyslexia. The participants with dyslexia also performed significantly worse on a semi-naturalistic task in which they were asked to remind the experimenter to save a data file 40 minutes after receiving this instruction.

Beyond this direct evidence, there are also reports of a greater tendency towards disorganization, forgetfulness, and absentmindedness in both children and adults with dyslexia (e.g., Augur, 1985; Leather, Hogh, Seiss & Everatt, 2011; Smith-Spark, 2000; Smith-Spark, Fawcett, Nicolson & Fisk, 2004). In addition, dyslexia-related difficulties have been reported in organization (Torgeson, 1977) and planning (Levin, 1990), both of which would appear to make demands on cognition which overlap with those involved in PM.

Time perception deficits have also been reported in dyslexia (e.g., Bruno & Maguire, 1993; Khan et al., 2014; Klein, 2002; Nicolson, Fawcett & Dean, 1995; Tallal, 1980; Wolff, 2002). Whilst these papers address time perception in the milliseconds to seconds range rather than the longer durations typically associated with TBPM tasks, they do suggest that difficulties with perceiving duration may have an impact upon PM. The study of the relationship between time perception and TBPM accuracy has yielded contradictory results (Mackinlay, Kliegel & Mäntylä, 2009; McFarland & Glisky, 2009) but, in the main, time perception ability seems to be more closely related to monitoring behaviour than the accuracy of PM responses, such that poorer temporal abilities have been found to be associated with more frequent clock checks (Labelle, Graf, Grondin & Gagné-Roy, 2009; Mioni & Stablum, 2014). However, in argument against this explanation for dyslexia-related TBPM difficulties, Smith-Spark et al. (2016b) found that their group with dyslexia made fewer, rather than more, clock checks. Furthermore, the pattern of clock checks did not give any indication of different checking strategies being used by adults with dyslexia relative to those without dyslexia.

There is, therefore, direct evidence to indicate that PM is poorer in individuals with dyslexia (Khan, 2014; Smith-Spark et al., 2016a, 2016b). This is supplemented by broader evidence suggesting greater disorganization, poorer planning, and forgetfulness in dyslexia (e.g., Augur, 1985; Levin, 1990; Smith-Spark, 2000; Smith-Spark et al., 2004; Torgeson, 1977). However, this corpus of research is small and it remains an open question as to how widespread dyslexia-related PM deficits actually are under both laboratory and everyday conditions. The current study sought to shed light on this by using a well-established objective measure of PM (the MIST; Raskin et al., 2010) to compare the performance of IQ-matched adults with and without dyslexia across a range of different task types, time delays, and response types. The second aim of the study was to obtain a more focused understanding of how PM was affected by dyslexia in day-to-day life. To this end, a questionnaire dedicated entirely to the assessment of PM, the PMQ (Hannon et al., 1995) was used as a subjective measure of PM and administered to the same sample of participants who completed the MIST.

The MIST (Raskin et al., 2010) was originally developed to assess clinical populations and has been used to identify PM deficits across a variety of groups and conditions (Pirogovsky, Woods, Filoteo & Gilbert, 2012; Poquette et al., 2013; Smith-Spark, Moss & Dyer, 2016; Weinborn, Woods, Nulsen & Park, 2011; Woods et al., 2007). Whilst it has been argued to be a relatively blunt index of PM abilities in non-clinical populations (e.g., Poquette et al., 2013), Kamat et al. (2014) have recently demonstrated its validity in measuring the PM of healthy elderly adults. The MIST consists of eight PM tasks, scores on which contribute to six scales. Two MIST scales relate to the time interval between intention formation and intention execution, with there being two different time intervals over which the intention needs to be retained (two- and 15-minutes). Two further scales differentiate between the types of PM cue which are presented to participants, with cues being either event- or time-based. Finally, the type of response required of the participant is represented by two scales, with the PM intention being enacted with either a verbal or action-based response. Participants are also tested on their retrospective recognition of the PM instructions after the MIST has been administered, allowing some indication of whether PM failures reflect failures of the retrospective or prospective components of PM. The MIST, therefore, allows PM performance to be gauged across a range of task demands, timeframes, and response types.

Deficits in adults with dyslexia were expected to be uncovered on the MIST (Raskin et al., 2010). A group difference in total score on the MIST was anticipated based on the self-report findings of Khan (2014) and Smith-Spark (2000; 2016a). At a finer-grained level, group differences in response to time cues were predicted on the basis of the laboratory-based TBPM task employed by Smith-Spark et al. (2016b). It remained to be seen whether there would be an effect of dyslexia on the remaining MIST scales.

Furthermore, from the perspective of the phonological processing difficulties typically associated with the condition (e.g., Castles & Friedmann, 2014; Vellutino et al., 2004), it could be argued that people with dyslexia may fail to encode verbal PM instructions effectively or that these instructions may be more poorly represented in retrospective memory (c.f., Smith-Spark & Moore, 2009). Such a difficulty would make the timely and effective access of the instructions at the point at which they are needed more problematic and leading to more error-prone PM. Problems in working with phonological information might also manifest themselves in poorer performance by the adults with dyslexia on MIST tasks requiring verbal responses (e.g., writing something down or saying something to the experimenter) in contrast to those requiring action responses (e.g., passing the experimenter a specified item). In addition, dyslexia-related problems with retrospective memory have previously been self-reported (Khan, 2014; Smith-Spark et al., 2016a) and found experimentally over varying timeframes (Huestegge, Rohrβen, van Emingen-Marbach, Pape-Neumann & Heim, 2014; McNamara & Wong, 2003; Menghini, Carlesimo, Marotta, Finzi & Vicari, 2010; Nelson & Warrington, 1980). Such difficulties might show themselves in the participants with dyslexia recalling fewer PM instructions correctly when questioned about them retrospectively.

The PMQ (Hannon et al., 1995) has been widely used as a self-report measure of the frequency with which everyday PM failures are experienced. It has been administered to a wide range of different populations (e.g., Cuttler & Taylor, 2012; Heffernan, Ling & Bartholomew, 2004; Heffernan et al., 2005; Montgomery & Fisk, 2007; Palmer, Durkin & Rhodes, 2015). Three PMQ subscales are designed to probe the frequency with which errors occur in response to different types of PM (namely long-term episodic, short-term habitual, and self-initiated). In addition to these three subscales, the Techniques Used to Assist Recall subscale investigates the frequency with which individuals use different types of strategy to aid their PM.

On the basis of previous self-report findings (Khan, 2014; Smith-Spark et al., 2016a) obtained from Smith et al.'s (2000) PRMQ, it was predicted that adults with dyslexia would report significantly more frequent PM problems on the PMQ (Hannon et al., 1995). It was an open question as to whether different patterns of results would be found on the PM error subscales as the self-report findings using the PRMQ had indicated a generally depressed profile of performance. Due to the provisions in place to support the individuals with dyslexia in UK educational settings, it was also predicted that there would be a group difference on the Techniques Used to Assist Recall subscale. These provisions emphasize the use of a range of study-related tools to support performance. The group with dyslexia was thus expected to report a greater use of, and reliance on, mnemonic and technological aids to assist their memory. However, Bacon, Parmentier, and Barr (2013) have reported that adults with dyslexia find it difficult to initiate effective strategies voluntarily on tasks (see also Meltzer, 1991, and Torgeson & Goldman, 1977), so they may not use tools and aids as strategically and effectively as they might in the absence of training in their use. It was, therefore, predicted that the group with dyslexia would still self-report higher rates of PM failure even after controlling for their expected greater use of aids to assist memory.

2. Method

2.1 Participants

Sixty native English speaking university students (45 females, 15 males, mean age = 24 years, *SD* = 4) were assigned initially to one of two groups on the basis of their self-declared dyslexia status, resulting in a group of 30 participants with dyslexia (21 females, 9 males) and a group of 30 participants without dyslexia (24 females, 6 males). There was no statistically significant difference in age between the two participant groups. Descriptive and inferential statistics performed on the background measures are displayed in Table 1. Course credit or a small honorarium was given to the participants in appreciation of their time.

TABLE 1 ABOUT HERE

The self-declared dyslexia status of each participant was then checked. The participants who stated that they had dyslexia showed the researcher an educational psychologist's report to confirm their diagnosis. The participants without dyslexia were asked, prior to testing, whether they had ever experienced problems with reading or spelling. None reported that they had. Whilst self-reports of not having dyslexia have been found to be highly accurate by Nicolson and Fawcett (1997), literacy measures were administered to all of the participants in order to provide a further validation of the participant groupings.

The Nonsense Word Reading Passage (NWR) from the Dyslexia Adult Screening Test (DAST; Fawcett & Nicolson, 1998) was used to assess reading ability. This test consisted of a short passage containing a mixture of real words and orthographically legal nonsense words. Even adults with dyslexia whose reading is otherwise compensated show continued difficulties with the decoding of novel nonsense words (Brachacki, Fawcett & Nicolson, 1994; Finucci et al., 1976). The DAST NWR is, thus, a powerful indicator of the continuing effects of dyslexia in adulthood. Performance of the test was timed and accuracy was recorded. The participants incurred scoring penalties for slow and/or inaccurate reading as set out in the standardised instructions. These speed and accuracy measures were combined to give a composite measure of performance, with higher scores indicating better reading performance. The group with dyslexia performed significantly worse on the composite NWR score.

The spelling component of the Wechsler Objective Reading Dimensions (WORD; Wechsler, 1993) was administered in order to obtain a measure of spelling ability. The participants were presented with a series of words of increasing difficulty to spell. Each word was read out loud, then put in the context of a spoken sentence, then read out loud once more. In line with the standardized test instructions, testing terminated after six successive incorrect spellings. A raw score out of 50 was calculated from the participants' responses. Scores of 42/50 and greater indicated a spelling age of greater than 17 years (the ceiling spelling age on the WORD) and thus placed the participant in the typical adult range. On average, the group with dyslexia produced significantly lower raw spelling scores than the group without dyslexia. All of the participants without dyslexia obtained spelling ages which were greater than 17 years, whilst 14 of the participants with dyslexia obtained spelling ages of 17 years or less.

Four subscales of the Wechsler Adult Intelligence Scale- Fourth UK Edition (WAIS-IV; Wechsler, 2010) were administered to all of the participants. The Comprehension and Vocabulary subscales were taken from the Verbal Scale and the Block Design and Picture Completion subscales were employed from the Performance Scale. Turner (1997) has argued that none of these measures are sensitive to the presence of dyslexia and, thus, provide a means of comparing IQ that is independent of its effects. Scaled scores on the four subscales were combined to calculate a short-form IQ for each participant, using the method set out by Turner. No significant group difference in short-form IQ was found.

2.2 Materials and Design

The PMQ (Hannon et al., 1995) consisted of 52 items distributed across four subscales. Three of these subscales investigated the frequency with which the participants felt that they had encountered PM failures in the week, month, or year prior to testing. Different timeframes were used depending on the subscale from which the question came. The 14-item Long-term Episodic subscale addressed memory intentions which needed to be held in memory for an extended number of hours or days before they could be executed and which did not occur frequently (e.g., “I missed appointments I had scheduled”). The 14-item Short-term Habitual subscale probed errors relating to tasks which have to be performed regularly and which involved short-time intervals between the formation of an intention and its execution (e.g., “I forgot to lock the door when leaving my apartment or house.”). The 10-item Internally-cued subscale assessed failures on PM tasks which had no external cues to act as reminders of the intention (e.g., “I was driving and temporarily forgot where I was going.”). The 14-item Techniques Used to Assist Recall subscale investigated the frequency with which strategies and other aides-memoire were used over the past week to support PM. Questions on this subscale related to planning and the use of rehearsal and reminders to aid PM performance were presented (e.g., “I write myself reminder notes.”). Responses were made along scales numbered from 0-8 with verbal descriptors underlying the extreme ends of the scale as well as its midpoint (i.e., “Never”, “Two”, and “Four or more times”). A “not applicable” (N/A) option was also provided for each question.

An overall score was derived from the mean response to all 52 questionnaire items, omitting all N/A responses from the calculation of the mean. A higher overall score on the PMQ reflected a greater self-reported propensity to PM failure. Similarly, scores for each subscale were calculated by obtaining the mean response for all questions which had received a response between zero and eight. Higher scores on the Long-term Episodic, Short-term Habitual, and Internally-cued subscales represented a greater frequency with which PM was reported to go awry. Higher scores on the Techniques Used to Assist Recall subscale indicated that mnemonic strategies and tools were more frequently used to support PM.

Parallel Form B of the MIST (Raskin et al., 2010) was used. The MIST's eight tasks required responses at different points during the 30-minute duration of the test administration, whilst the participant was engaged in an ongoing word-search puzzle. Performance on these eight tasks contributed towards six scales, with each individual task providing data for three of these scales. The different PM tasks overlapped with each other, such that there were multiple intentions which needed to be held simultaneously in memory whilst the participant performed the ongoing task. The MIST's optional naturalistic TBPM task was also administered, with a telephone extension connected to an answering machine being used to record responses.

The scoring of responses on the MIST followed the standard method (Raskin et al., 2010), with each PM task being scored from zero to two. Better performance was thus reflected in higher scores. A score of two indicated that the task was performed correctly, a score of one that it was performed partially correctly, and a score of zero indicated that it was not performed at all. The total score from each scale thus ranged from zero to eight and gave a maximum total score of 48. Four of the eight PM tasks contributed to each of six MIST scales (namely, time cue, event cue, verbal response, action response, two-minute delay, and 15-minute delay). Following the MIST scoring guidelines for the 24-hour delayed task, no points were awarded to participants who failed to leave a voicemail message for the experimenter, one point was given to individuals who left a voicemail message but did not produce the correct message content, and two points were awarded to participants who left the voicemail message containing the correct content within one hour either side of the target time for completing the task.

2.3 Procedure

Informed consent was acquired from all of the participants prior to testing. Background information about the participants was collected before the short-form IQ and literacy measures were administered.

The participants were asked to complete the PMQ (Hannon et al., 1995), rating the relative frequency of different types of PM failure by circling their response on the scale provided for each question. Two example questions and responses were presented in the instruction phase. The participants circled the N/A response when questions were not relevant to them. The attention of the participants was brought to the varying temporal descriptors used on different sections of the questionnaire. These descriptors related variously to the frequency of PM failures over a week, a month, or a year.

The participants were seated at a desk with a clear view of a large digital clock. The standardized MIST instructions (Raskin et al., 2010) were presented verbally and the participants were given the opportunity to ask questions. After this, the participants worked on the word search puzzle for the 30-minute duration of the test, receiving eight standardized PM verbal instructions at different points during the administration of the test. When the appropriate time or cue to respond arrived, the participants were required to perform a certain action or to provide a particular verbal response.

When the participants had completed the eight MIST PM tasks, an eight-item multiple choice recognition check-list was read out loud to the participants. This asked about the contents of each of the PM instructions. For each multiple choice item, the participants were asked to choose, from three options, the correct PM instruction given to them.

At the end of the testing session, the participants were asked to leave a voicemail message exactly 24 hours later, in which they were required to state their name and the number of hours that they had slept the previous night. The experimenter's telephone number was given to the participants verbally. The participants were asked to save the telephone number directly to their mobile 'phone contacts list in order to prevent them from creating a paper-based note of the number which could later act as a cue to memory.

The participants were verbally debriefed at the end of the study.

3. Results

3.1 The PMQ

The PMQ was found to have a good to high reliability (PMQ total, Cronbach's $\alpha = .92$; Long-term Episodic, Cronbach's $\alpha = .92$; Short-term Habitual, Cronbach's $\alpha = .75$; Internally-cued, Cronbach's $\alpha = .95$; Techniques Used to Assist Recall, Cronbach's $\alpha = .87$).

On average, the group with dyslexia (mean = 2.97, $SD = 1.10$) produced higher overall PMQ scores than the group without dyslexia (mean = 1.97, $SD = 0.76$). An unrelated t-test indicated that the group with dyslexia reported significantly more problems with PM than the group without dyslexia, $t(51.629) = 4.11$, $p < .001$, $d = 0.94$. Levene's test was significant so a reduced number of degrees of freedom are reported.

The group with dyslexia (mean = 3.98, $SD = 1.74$) reported using techniques to assist memory significantly more frequently than the group without dyslexia (mean = 3.09, $SD = 1.50$), $t(58) = 2.12$, $p = .038$, $d = 0.53$.

In order to explore the different facets of PM failure probed by the PMQ, a multivariate analysis of covariance (MANCOVA) was used to explore the responses to the individual subscales, with participant group (levels: group with dyslexia and group without dyslexia) entered as the between-subjects factor. Scores for the three types of PM (Long-term Episodic, Short-term Habitual, and Internally-cued) were entered as dependent variables into the analysis, with higher scores indicating more frequent PM failures. Scores on the Techniques Used to Assist Recall scale were entered as the covariate (given the significant group difference in the frequency with which tools and techniques were used to support PM).

The MANCOVA indicated that there was a significant multivariate effect of participant group on self-reported PM failure scores, Wilks' $\Lambda = .816$, $F(3, 55) = 4.12$, $p = .010$, $\eta_p^2 = .184$. Follow-up univariate F-tests indicated that the group with dyslexia reported significantly more problems than the group without dyslexia on both the Long-term Episodic and Internally-cued subscales. Whilst the group with dyslexia indicated that, on average, they had more frequent problems on the Short-term Habitual subscale, this difference was not found to be statistically significant. The group means and univariate F-test statistics for the three PMQ subscales are shown in Table 2.

TABLE 2 ABOUT HERE

3.2 The MIST

3.2.1 Overall MIST score

The total MIST score of the participants with dyslexia (mean = 41.23, *SD* = 6.83) was lower than that of the participants without dyslexia (mean = 44.27, *SD* = 4.22). An unrelated *t*-test indicated that this group difference was statistically significant, $t(48.325) = 2.07$, $p = .044$, $d = 0.52$. Levene's test was significant so reduced degrees of freedom are reported.

3.2.2 Comparison of scale scores

The mean descriptive statistics for the six MIST scales are shown in Table 3. Separate two-way mixed-measures analyses of variance (ANOVAs) were performed on the three MIST scale pairs (i.e., time cue vs. event cue, two-minute delay vs. 15-minute delay, and action response vs. verbal response). In each case, participant group (levels: with dyslexia and without dyslexia) was entered as the between-subjects factor.

TABLE 3 ABOUT HERE

3.2.2.1 Delay interval

The adults with dyslexia (mean = 6.85, *SEM* = 0.18) were significantly less accurate than the adults without dyslexia (mean = 7.38, *SEM* = 0.18) on the scales relating to the duration of the interval between forming an intention and having the opportunity to act upon it. This group difference was statistically significant, $F(1, 58) = 4.63$, $MSE = 1.842$, $p = .036$, $\eta_p^2 = .074$.

Prospective memory performance was significantly better when there was a two-minute delay (mean = 7.83, *SEM* = 0.06) than when there was a fifteen-minute delay (mean = 6.40, *SEM* = 0.22), $F(1,58) = 49.63$, $MSE = 1.242$, $p < .001$, $\eta_p^2 = .461$.

The participant group x delay interval interaction was not statistically significant, $F(1, 58) = 2.68$, $MSE = 1.242$, $p = .107$.

3.2.2.2 Cue type

On the two cue type scales, scores were lower for the adults with dyslexia (mean = 6.88, *SEM* = 0.17) than the adults without dyslexia (mean = 7.37, *SEM* = 0.17), but this difference was not significant, $F(1, 58) = 4.50$, $MSE = 1.804$, $p = .053$.

The participants responded significantly more accurately when presented with an event-based cue (mean = 7.62, *SEM* = 0.11) than a time-based cue (mean = 6.63, *SEM* = 0.19), $F(1, 58) = 24.59$, $MSE = 1.18$, $p < .001$, $\eta_p^2 = .298$.

Participant group and cue type interacted significantly, $F(1, 58) = 5.15$, $MSE = 1.18$, $p = .027$, $\eta_p^2 = .082$. Post hoc unrelated t-tests indicated that, whilst there was no significant group difference in scores when cues were event-based, $t(58) < 1$, $p = .883$, the group with dyslexia were significantly less accurate than the group without dyslexia when cues were time-based, $t(53.026) = 2.43$, $p = .019$, $d = 0.60$. Levene's test was significant for the time-based analysis so equal variances were not assumed. The interaction plot is shown in Figure 1.

FIGURE 1 ABOUT HERE

3.2.2.3 Response type

Regardless of whether a verbal or action response was required, the adults with dyslexia (mean = 6.88, *SEM* = 0.17) scored significantly lower than the adults without dyslexia (mean = 7.38, *SEM* = 0.17), $F(1, 58) = 4.29$, $MSE = 1.748$, $p = .043$, $\eta_p^2 = .069$.

Prospective memory tasks requiring verbal responses (mean = 7.30, *SEM* = 0.12) resulted in slightly better performance than those that demanded action responses (mean = 6.97, *SEM* = 0.17), but this difference was not statistically significant, $F(1, 58) = 3.62$, $MSE = 0.920$, $p = .062$.

There was no significant interaction between participant group and response type, $F(1, 58) < 1$, $MSE = 0.920$, $p = .570$.

3.2.3 Retrospective recognition questionnaire

Recognition of the eight PM instructions was more-or-less equivalent across the participants with dyslexia (mean = 7.84, *SD* = 0.37) and the participants without dyslexia (mean = 7.90, *SD* = 0.31). No significant group difference in retrospective recognition of the PM instructions was found, $t(47.406) = 1.60$, $p = .310$. Again, Levene's test was significant so equal variances were not assumed.

3.2.4 Twenty-four hour delayed PM task

A Chi-square analysis was performed on the data from the 24-hour delayed PM task. A significant association between participant group and the type of response made to the 24-hour delayed PM task was found, $\chi(2, N = 60) = 6.86$, $p = .032$, $\varphi_c = .338$. The adults with dyslexia were more likely to fail to perform the PM task than to remember to carry it out, whilst the reverse pattern of performance was found in the adults without dyslexia. The observed frequencies are shown in Figure 2.

FIGURE 2 ABOUT HERE

4. Discussion

The PM abilities of the adults with dyslexia were found to be impaired on measures designed both to assess typical, everyday performance and optimal performance under laboratory conditions (c.f. Stanovich, 2009). Dyslexia-related PM problems are, therefore, evident at both the reflective and algorithmic levels of Stanovich's (2009) framework. The findings, thus, corroborate both previous self-report data (Khan, 2014; Smith-Spark et al., 2016a) and experimental work (Smith-Spark et al., 2016b) in indicating dyslexia-related deficits in PM and, moreover, do so with the same groups of individuals responding to both types of measure.

On the MIST (Raskin et al., 2010), the group with dyslexia performed significantly less well overall than the group without dyslexia, indicating generally less accurate PM. When the MIST scale pairs were considered, there were main effects of participant group on both delay interval and response type, with the group difference on cue type falling short of statistical significance (most likely due to the relatively strong performance of the group with dyslexia in response to event cues). Further to these main effects, a significant participant group x cue type interaction was also found. Whilst the two groups performed at an equivalent level when event cues were presented, the group with dyslexia performed significantly worse when time cues were used. Time-based PM has been argued to be more self-initiated in nature (e.g., Einstein, McDaniel, Richardson, Guynn & Cunfer, 1995) and is, thus, more cognitively demanding than simply responding to environmental cues. Whilst performance in response to event cues was close to ceiling (thus making group differences harder to detect), the absence of a group difference is consistent with the results of two computerized EBPM tasks reported by Zięcik (2015) on which no group differences between adults with and without dyslexia were uncovered and on which performance was not close to ceiling (with mean accuracies ranging from 71 to 83% across both participant groups). Although the data seem to indicate that EBPM is not affected by dyslexia, it is perilous to conclude too much from null results. Moreover, it should be noted that the delay intervals involved in performance of the MIST event cue tasks were relatively short (two or 15 minutes) and with very salient cues (such as a pen being handed over to the participant by the experimenter). It may be that deficits in EBPM can be found over longer delay intervals and/or with less salient cues to facilitate remembering of the intention. Further work is required to explore this proposition.

There were no further significant interactions between MIST scale pairs, although there was a non-significant trend towards the PM performance of the group with dyslexia being more detrimentally affected by the shift to a longer delay between forming an intention and having the opportunity to act upon that intention.

One possible explanation for the poorer MIST performance in dyslexia might lie in a problem with verbally encoding the instructions in the first place, as would be predicted by the core difficulties in phonological processing associated with the condition (e.g., Castles & Friedmann, 2014; Vellutino et al., 2004). However, two lines of argument present themselves against this conclusion. Firstly, if it were simply a failure to process the PM instructions effectively which led to the PM deficits found in the group with dyslexia, then this failure should apply equally to all of the MIST scales. The data indicate clearly that it did not. Instead, the data revealed selective impairments of PM when time cues were used rather than event cues but not when verbal PM responses were required rather than action-based responses. Secondly, the participants with dyslexia were no worse than the participants without dyslexia at recognizing the PM instructions when probed retrospectively. Nonetheless, and despite the recognition test being a well-established part of the MIST (e.g., Raskin et al., 2010), it should be acknowledged that there are considerable differences between recall and recognition. Recognizing an instruction from a choice of three options places different (and reduced) cognitive demands on the individual than having to access the retrospective component of the PM intention during ongoing task performance (see Smith-Spark, 2017). This issue needs to be explored further in future work. However, it would seem, prima facie, that the problems with PM experienced by adults with dyslexia, mainly centred around TBPM, are more likely to be related to the prospective component of PM. As a result, broader theoretical conceptualizations of dyslexia may need to be appealed to in order to explain the results in terms of, for example, problems with the allocation of attention between ongoing and PM performance (e.g., Facoetti et al., 2000; Hari & Renvall, 2001; Nicolson & Fawcett, 1990) and/or executive functioning (e.g., Smith-Spark & Fisk, 2007; Varvara, Varuzza, Sorrentino, Vicari & Menghini, 2014).

Not only was PM performance lower in the group with dyslexia under laboratory conditions, but it was also less accurate in the MIST’s 24-hour delayed PM task (Raskin et al., 2010), wherein remembering the intention to telephone the experimenter occurred in naturalistic, everyday conditions. Compared with the adults without dyslexia, the adults with dyslexia were significantly more likely to forget to leave the telephone message for the experimenter. This result indicates that dyslexia-related problems with TBPM can be found under naturalistic conditions, thereby extending previous naturalistic work by Smith-Spark et al. (2016b) beyond the laboratory setting and providing something of a bridge to the consideration of everyday PM usage under typical conditions.

As stated previously in this section, the results of the PMQ (Hannon et al., 1995) are consistent with previous self-report work on PM in dyslexia (Khan, 2014; Smith-Spark et al., 2016a). However, the questionnaire data built upon previous research in identifying more specifically where adults with dyslexia feel their problems with PM lie, with particular problems being identified with one-off long-term PM and self-initiated PM. This is an important point since, as Smith-Spark (2017) argues, the consequences of PM failure in adulthood (where the adult bears a considerably larger responsibility for ensuring that his or her PM functions successfully) are likely to be much greater than in childhood (where much of the child’s PM will be offloaded to a parent or caregiver; c.f., Spurrett & Cowley, 2010). By documenting areas of relative strength and weakness, appropriate support plans can be developed to ensure that adults with dyslexia achieve their full potential in educational and workplace settings.

The current study, therefore, adds to the understanding of the types of PM which people with dyslexia feel that they find most difficult and, beyond this, allows the use of memory aids to be controlled for statistically when examining the relative frequency of PM failure across groups.

Greater use of techniques to assist memory was indeed reported by the group with dyslexia on the Techniques Used to Assist Recall subscale. Since provision of educational support for adults with dyslexia in the UK emphasizes the use of technology and other aids to assist learning, it could be viewed as reassuring that these tools are being used frequently by university students with dyslexia to support their PM. However, significant group differences on the Long-term Episodic and Internally-cued subscales were found after controlling for differences in scores on the Techniques Used to Assist Recall subscale.

After controlling for differences in the use of tools and technology to facilitate remembering, the adults with dyslexia reported significantly more problems on the Long-term Episodic subscale. This subscale assessed respondents' perceptions of their ability to perform successfully one-off or infrequently occurring PM tasks over longer intervals. Many of the items making up the Long-term Episodic subscale draw on TBPM rather than EBPM processes, suggesting that TBPM may be more adversely affected by dyslexia than EBPM.

In support of this argument, greater difficulties were also reported by the participants with dyslexia on the Internally-cued subscale. Self-initiated processes have been argued to be relied upon by a greater extent by TBPM (Einstein et al., 1995). Differences on this subscale may, thus, also be indicative of a dyslexia-related deficit in TBPM.

There was no group difference in the frequency of PM failures reported on the Short-term Habitual subscale. From this result, it would appear that when a PM task is performed regularly and there is a short time interval between intention formation and the opportunity to act upon that intention, no self-perceived differences emerge between adults with dyslexia and adults without dyslexia.

Since the adults with dyslexia still viewed PM failures as occurring more frequently in their day-to-day lives despite the greater use of mnemonic support, the findings raise a potentially important implication for the support of adults with dyslexia. The results suggest that the tools and strategies reportedly being used are not being employed as effectively as they could be. More strategic use of the tools and strategies available may need to be demonstrated to adults with dyslexia in order for them to gain the maximum benefit that they can from them. Bacon et al. (2013) have argued that adults with dyslexia are less likely to initiate a new strategy for themselves when problem-solving but are fully capable of adopting it if shown how it should be applied. Simply providing people with dyslexia with technological tools may not be sufficient to support them; instead, training in their use in everyday settings and in response to specific real-world tasks or problems may be required.

There are limitations when probing aspects of cognition with self-report measures (e.g., Rabbitt & Abson, 1990). A general problem with self-report measures of memory is that they do not always correlate highly with either objective laboratory-based memory tests or clinical observations (e.g., Craik, Anderson, Kerr & Li, 1995; Herrmann, 1984). Questionnaires probing PM are no exception to this criticism and the strength of correlations between self-report measures of PM and laboratory-based measures is generally rather varied (e.g., Kliegel & Jager, 2006; Uttl & Kibreab, 2011; although see Hannon, Adams, Harrington, Fries-Dias & Gibson, 1995). However, rather than taking this evidence to indicate that self-report measures are fundamentally flawed, the lack of correlation may reflect the different levels of cognition which are being probed by questionnaire measures and laboratory-based tasks (c.f., Stanovich, 2009; Topiak et al., 2013).

Given the number and level of detail of the questions comprising the PMQ (Hannon et al., 1995), coupled with the absence of a proxy-rating version, it was decided not to take corroborative measures from close associates of the participants (as has been done in previous self-report work on the everyday cognition of adults with dyslexia; Smith-Spark et al., 2004; Smith-Spark et al., 2016a). Dyslexia in adulthood is often accompanied by lowered self-esteem (e.g., Riddick, Sterling, Farmer & Morgan, 1999) and this may play out in an unduly negative view of the PM abilities of the group with dyslexia when completing the self-report questionnaire. However, there are two arguments against this potential weakness in the findings. Firstly, the objective data obtained from the MIST (Raskin et al., 2010) can be argued to provide corroborative, convergent evidence for the PMQ results, with problems with self-initiated PM being found to be problematic using both approaches. Secondly, previous questionnaire work using proxy-ratings to assess the cognition of adults with dyslexia has found that the perceptions of both respondents and their close associates are in close agreement (Smith-Spark et al., 2004; Smith-Spark et al., 2016a). Taken together, these two arguments suggest that the responses to the PMQ reported in the current paper are likely to be reliable and, in conjunction with the laboratory measures reported in this paper and in Smith-Spark et al. (2016b), provide useful convergent evidence for the existence of PM deficits in adults with dyslexia.

Conclusions

Drawing together the objective and subjective measures used in the current paper, PM would appear to be impaired in dyslexia at both the reflective and algorithmic levels of cognition (Stanovich, 2009). Given this seeming pervasiveness, such problems may have a considerable impact on the daily working and social lives of individuals with dyslexia. These findings could, therefore, have important implications for supporting people with dyslexia in everyday life. For instance, people with dyslexia could be advised to convert TBPM to EBPM tasks wherever possible (given what seem to be their specific difficulties with TBPM), either through the use of technology (such as smartphones or calendar devices set to give visual or auditory reminders about upcoming tasks) or through intention implementation (e.g., Gollwitzer & Sheeran, 2006) to set out when, where, and how the goal of remembering and acting upon a delayed intention will be met. As well as exploring the relative effectiveness of these methods of reducing the likelihood of PM failure, further research should aim to understand why TBPM (or, more generally, self-initiated PM) would seem to be particularly prone to the effects of dyslexia, exploring the cognitive mechanisms underlying TBPM performance in more depth.

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Table 1

Background characteristics for the two participant groups. Standard deviations are shown in parentheses.

Scale	Group with dyslexia	Group without dyslexia	*Unrelated t-test*			
			t	*df*	*p*	*d*
Age (years)	24 (4)	24 (5)	< 1	58	.953	-
WAIS-IV Short-form IQ	110 (10)	108 (9)	< 1	58	.534	-
DAST NWR score	81 (11)	92 (5)	5.91	32.856	< .001	1.22
WORD spelling raw score	42 (4)	45 (1.93)	4.67	42.220	< .001	1.04

Table 2

Group mean scores and univariate ANCOVA results for the PMQ subscales relating to PM failure.

PMQ subscale	Mean (SD)		Univariate *F*-test statistics			
	Group with dyslexia	Group without dyslexia	$F(1, 57)$	MSE	p	η_p^2
Long-term episodic	2.97 (1.65)	1.90 (0.89)	8.46	1.78	.005	.129
Short-term habitual	0.84 (1.02)	0.43 (0.46)	3.48	0.64	.067	.057
Internally-cued	4.10 (2.02)	2.40 (1.30)	12.39	2.91	.001	.179

Bonferroni-corrected α-level = .017.

Table 3

Group means for the six MIST subtests. Standard deviations are shown in parentheses.

	Group with dyslexia	Group without dyslexia
Two-minute delay	7.73 (0.64)	7.93 (0.25)
Fifteen-minute delay	5.97 (2.03)	6.83 (1.26)
Event cue	7.60 (0.97)	7.63 (0.77)
Time cue	6.17 (1.70)	7.10 (1.24)
Verbal response	7.00 (1.11)	7.60 (0.77)
Action response	6.77 (1.57)	7.17 (1.02)

Figure 1

The participant group x cue type interaction.

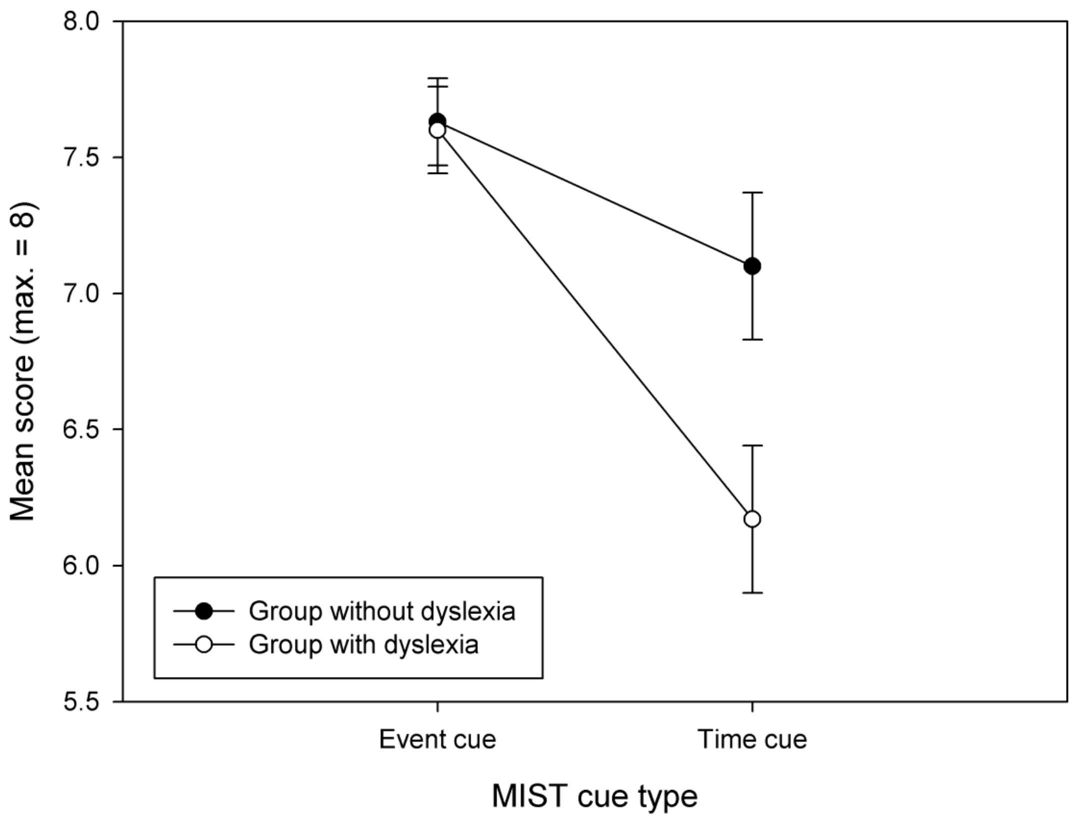

Figure 2

The association between participant group and type of response on the 24-hour delayed PM task.