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Prospective memory and quality of life in older and younger autistic adults☆

Amanda Roestorf [a,c], *Dermot M. Bowler* [a,*], *Sebastian B. Gaigg* [a] *and Patricia Howlin* [b]

[a] City St George's, University of London, Department of Psychology, London, UK
[b] King's College London, De Crespigny Park, London, UK
[c] Autistica UK, Suite B, London, UK

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ABSTRACT

Ageing in late adulthood is generally accompanied by diminished prospective memory (PM), which itself is associated with declining quality of life (QoL). Given that autistic individuals are often reported as having PM difficulties and diminished QoL, we aimed to establish whether these measures are also associated in these individuals as they grow older. We administered questionnaire measures of prospective and retrospective memory (PM and RM) and of overall and health-related quality of life (QoL) and experimental measures of time-based and event-based PM (TBPM and EBPM) to 35 autistic and 22 non-autistic adults aged from 23 to 80 years. The autistic participants reported higher levels of PM and RM difficulties than non-autistic participants but that these reports did not correlate with age nor with the experimental TBPM or EBPM measures in either group. Age correlated negatively with two of the experimental measures of TBPM for the non-autistic participants, replicating earlier studies. Autistic participants showed diminished performance on the TBPM but not the EBPM measures, replicating the majority of earlier PM studies in autism. Autistic participants also reported lower overall and health-related QoL, but there were no age-related differences for either measure in either diagnostic group. Self-reported PM and RM correlated significantly with health-related QoL in both the autistic and non-autistic participants. Overall QoL was positively associated with TBPM accuracy in the non-autistic participants. In addition to confirming earlier findings showing that autistic individuals have greater difficulties with TBPM compared to EBPM, our findings suggest that neither EBPM nor TBPM difficulties appear to adversely affect

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* *Corresponding author*. Department of Psychology, City, University of London, Northampton Square, London EC1V 0HB, UK.
E-mail addresses: amanda.roestorf@autistica.org.uk (A. Roestorf), d.m.bowler@city.ac.uk (D.M. Bowler).

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their overall or health-related QoL. The patterning of the autistic participants' results also suggests that the mechanisms underlying their performance on the tasks used in this study may differ from those of the non-autistic participants, pointing to the need for careful task analysis when designing future investigations.

1. Introduction

Autism spectrum disorder (or difference ASD)[1] hereafter called 'autism', is a set of neurodevelopmental conditions that affects over 1% of the general population (Lord et al., 2021) and is characterised by difficulties in social-communication and increased restricted and repetitive behaviours and altered sensory sensitivities (American Psychiatric Association, 2013). It may or may not be accompanied by intellectual disability of any level and may lead to considerable levels of diminished adaptation in everyday life (Ayres et al., 2018). The psychological features of autism have been systematically researched ever since it was first described by Kanner (1943) and Asperger (1991) with difficulties in a range of other cognitive functions such as enhanced focus on details leading to Weak Central Coherence (Happé & Frith, 1996), diminished influence of context on perception (Pellicano & Burr, 2012), over-precise perceptual representations (Van de Cruys et al., 2014) and executive functions (EF's; Demetriou et al., 2018; Xie, Sun, Yang, & Guo, 2020; see Happé & Frith, 2020 for review). Autistic children and younger adults also have a distinctive patterning of performance on memory tests that is characterised by relatively intact recognition memory and relatively poorer recall as well as difficulties with remembering the personally experienced past (see Boucher & Bowler, 2008; Desaunay et al., 2020; Griffin, Bauer, & Gavett, 2022 for reviews). This pattern is similar to that seen in healthy older non-autistic individuals which includes larger declines on free recall than on recognition memory tasks (Craik & McDowd, 1987; Cadar, Usher, and Davelaar (2018); Danckert and Craik (2013), greater reliance on external support when engaging in memory tasks (Craik, 2022) and diminished recollection and reduced remembering of the personally experienced past (Bastin, Van der Linden, Michel, & Friedman, 2004; Boywitt, Kuhlmann, & Meiser, 2012; Grady, 2012; Korkki, Richter, Jeyarathnarajah & Simons, 2020). In healthy ageing, these last difficulties are thought to be driven by a reduced capacity retrieve links between separate units of information, whether these are two distinct items or items and their contexts (Clark, Hazeltine, Freedberg, & Voss, 2018; Danckert & Craik, 2013; Endemann & Kamp, 2022; Grady, 2012; Greene & Naveh-Benjamin, 2022; Naveh-Benjamin, 2000) and all of which can have far-reaching effects on an individual's general adaptive functioning (Crook et al., 1986; Woods et al., 2015).

However, it is only in the last 10 years or so that scientists have begun to address systematically the patterning and psychological profile of autistic individuals as they enter the later stages of their lifespan (see Bowler, Geurts & Howlin., 2019; Torenvliet et al., 2023 for reviews). Some investigations report greater cross-sectional age-related differences in processing speed and visual working memory in autistic than in non-autistic individuals (Tse, Crabtree, Islam & Stott, 2019) or greater autism-related, cross-sectional and longitudinal age-related rates of clinically meaningful declines or differences in verbal memory (Pagni et al., 2022, pp. 810–1823) while others report parallel patterns of cross-sectional age-related differences in non-autistic and autistic individuals (Geurts & Vissers, 2012; Lever & Geurts, 2016).

A particular aspect of memory difficulty that is common to healthy aging and to autism is diminished unprompted remembering and execution of delayed intentions to act, often referred to as *Prospective Memory* (PM). Successful PM performance involves higher-level regulation and coordination of retrospective (RM) and prospective memories and their association with internal or external cues, all with the aim of carrying out a future action. As such it involves memory, executive functions and a capacity for planning and future thinking (Kliegel et al. 2016). Life-span studies of the typical population, show a peak in PM in the 3rd decade of life and a slow decline until the mid-70's when the decline is markedly steeper (Zuber & Kliegel, 2020). However, this global trajectory masks considerable variability that is often driven by task-related factors rather than random individual differences or non-random differences in factors such as executive functions. Prominent among these task factors is a distinction first made by Einstein and colleagues (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Einstein & McDaniel, 1990) based on whether some external event acts as a cue for performance of the intended action (such as leaving a letter to be posted on the hall table to act as a reminder to post the letter when you go out to work (*Event-Based Prospective Memory* EBPM), and whether the prompt or reminder is intrinsic or extrinsic to ongoing activity (McDaniel & Einstein, 2000) necessitating a shift in attention from the ongoing task. Alternatively, the delayed intention needs to be executed after a specified time period has elapsed (for example, remembering to take medication 30 min after a meal (*Time Based Prospective Memory* - TBPM), which adds the dimension of the participant's temporal awareness to the cluster of psychological processes encompassed in PM. The complex interaction of both non-memory and memory processes required in the performance of PM tasks has resulted in an equally complex pattern of findings on age-related PM (see Zuber & Kliegel,

[1] We have chosen to use the terms 'autism' and 'autistic' ('condition first' language), respecting the modal preference of the autism community described by Kenny et al. (2016).

2020 for further discussion) although the general consensus is that on laboratory-based PM tasks, healthy older individuals to show greater difficulties on lab-based TBPM than lab-based EBPM (Henry, MacLeod, Phillips, & Crawford, 2004).

Research on PM in autistic children and younger adults has revealed fewer autism-related performance reductions on EBPM (Altgassen, Schmitz-Hübsch, & Kliegel, 2010; Altgassen et al., 2012bib_altgassen_et_al_2012; Brandimonte, Filippello, Coluccia, Altgassen, & Kliegel, 2011; Dehnavi & Khan, 2024; Henry et al., 2014; Jones et al., 2011; Kretschmer et al., 2014; Sheppard, Bruineberg, Kretschmer-Trendowicz, & Altgassen, 2018; Williams, Boucher, Lind, & Jarrold, 2013, 2014; Yi et al., 2014 although see Altgassen et al., 2012; Sheppard, Matchanova, Sullivan, Kazimi, & Woods, 2020) and diminished TBPM performance (Altgassen, Williams, Bölte, & Kliegel, 2009; Altgassen et al., 2012; Henry et al., 2014; Kretschmer et al., 2014, Williams et al., 2013, 2014. In a meta-analysis and methodological review, Landsiedel, Williams, and Abbot-Smith (2017) concluded that although there is ' … evident time-based PM impairment [*sic*] in ASD … ' (p. 663), there is considerable heterogeneity in the findings, especially in relation to the possible processes underlying poor TBPM performance. The only study to date that has investigated EBPM and TBPM in older autistic individuals (Groenman, Torenvliet, Radhoe, van Rentergem, van der Putten, Altgassen & Geurts, 2024)[2] tested autistic and non-autistic adults' (age range from 30 to 85 years) performance on the *Amsterdam Breakfast Task*, an adaptation of the Dresden Breakfast Task (Altgassen et al., 2012), which encompasses both TBPM tasks such as checking on items such as the temperature of the oven after a certain period of time and EBPM tasks such has responding to the sound of boiling water in a saucepan when boiling an egg. All these PM tasks happened within the context of emptying the dishwasher and putting cutlery and crockery back in the cupboard. Participants could also monitor the passage of time by calling upon an on-screen clock. Although Groenman et al. predicted *inter alia* that the performance of their autistic participants would be worse than that of their typical ones on TBPM but not on EBPM but that age and diagnosis would not interact for either type of PM, their results showed an overall age-related reduction in performance in both TBPM and EBPM, which was of similar size in both autistic and non-autistic participants. Although this parallel age-related difference mirrored that found in the majority of studies of retrospective memory discussed above, the absence of a diagnostic group difference in either EBPM or TBPM contrasts with earlier work just mentioned, leading Groenman et al. to question the ecological validity of laboratory tasks such as their Amsterdam Breakfast task, speculating that they might prompt older autistic adults to manage the deployment of attentional resources differently yet in a way that yields comparable performance to that of non-autistic comparison participants.

Quality of Life (QoL) is defined as 'an individual's perceptions of their position in life in the context of culture and value systems in which they live and in relation to their goals, expectations, standards and concerns' (World Health Organization Division of Mental Health, 1996, p. 3 cited in Simpson et al., 2024). Memory in general and PM in particular have been shown to play an important role in non-autistic adults' functional independence, activities of daily living and QoL (Hering, Kliegel, Rendell, Craik, & Rose, 2018; Tierney, Bucks, Weinborn Hodgson & Woods, 2016; Woods et al., 2015; Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2012) particularly when their levels of daily activities and their QoL decline with advancing age (Wrosch, Bauer, & Scheier, 2005). The consensus of a large body of research that an important mediator of these changes is PM decline (Hering et al., 2018; Woods et al., 2015), which can be crucial in poor health outcomes as well as overall QoL (Evans & Mottram, 2000; Pirogovsky, Woods, Filoteo, & Gilbert, 2012; Woods et al., 2012; Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012). Almost all activities in an individual's daily life involve some degree of retrospective and prospective memory. Shopping for oneself requires an ability to remember (retrospectively) items that have run out at home and possibly to remember (prospectively) to buy certain ingredients because a particular guest is coming to visit or take a letter to post when going shopping for other items. Time-based PM is also involved when food put on to cook needs to be checked periodically. Visits to healthcare professionals need to be remembered prospectively, as does the need to take regular medication at specific times. In this regard, medication mismanagement resulting from poor PM has been shown to lead to poor health QoL outcomes in older individuals (Pirogovsky et al., 2012; Rendell & Craik, 2000; Rendell & Thomson, 1993).

Autistic individuals are characterised by diminished quality of life at almost any age (Bishop-Fitzpatrick et al., 2016; Mason et al., 2019; Roestorf & Bowler, 2016; Roestorf, Howlin, & Bowler, 2022; van Heijst & Geurts, 2015; Yarar et al., 2022) whether measured by standardised instruments such as the World Health Organisation's WHOQoL-BREF (e.g. Kamio, Inada, & Koyama, 2013; van Heijst & Geurts, 2015) or other standardised self-report or informant-report instruments (see Ayres et al., 2018 for review) or ratings of outcomes based on the autistic clinical picture (Henninger & Taylor, 2013). Diminshed QoL in older-age individuals with autism does not appear to change significantly over a 2.4 year follow-up period in older (Mean age: 58.6 years) adults (Roestorf et al., 2022), and right across the life-span, level of QoL is better predicted by self-reported mental health issues such as anxiety or depression (Howlin, Moss, Savage, & Rutter, 2013; Mason et al., 2019; Moss, Mandy, & Howlin, 2017; Oakley et al., 2021; van Heijst & Geurts, 2015; Yarar et al., 2022), rather than by measures such as IQ or autism severity (Kim & Bottema-Beutel, 2019).

2. Aims of the present study

Because memory in general and PM in particular are associated with QoL in the general healthy ageing population (Hering et al., 2018; Woods et al., 2015) and because much of the existing literature on PM in autism speculates about but does not test the potential role of PM in the kinds of adaptive functioning that are inherent in good QoL, especially health-

[2] The present study was conceived and carried out before that of Groenman et al. (2024). This is reflected in the way our hypotheses were framed.

related QoL (Dehnavi & Khan, 2024, Lind & Williams, 2012; see Sheppard et al., 2018 for review), the ultimate aim of the present study is to explore the extent, if any, of how PM difficulties are related to overall and health-related QoL in our participants. To achieve this aim, we first needed to confirm existing findings of diminished QoL in younger and older autistic adults, hypothesising that irrespective of age, autistic individuals would perform similarly to earlier studies by showing poorer overall and health-related QoL than younger typical participants (Bishop-Fitzpatrick et al., 2016; Mason et al., 2019; Roestorf & Bowler, 2016; Roestorf et al., 2022; van Heijst & Geurts, 2015; Yarar et al., 2022) and that older non-autistic participants would report poorer QoL than younger ones (Caballero et al., 2013; Wrosch et al., 2005). The experimental findings of memory difficulties in the younger autistic populations (Boucher & Bowler, 2008; Desaunay et al., 2020; Griffin et al., 2022) led us to predict that self-reported levels of RM and PM difficulties in our older autistic participants would be higher than in the non-autistic participants and that this group would compare less well to non-autistic participants on experimental measures of TBPM than on measures of EBPM as has been found in the majority of earlier studies of younger autistic people (see Landsiedel et al. (2017 for review). We made similar predictions for the overall comparison between autistic and non-autistic participants irrespective of age but given the conflicting findings on age-related trajectories for general memory in autism (Geurts & Vissers, 2012; Lever & Geurts, 2016; Pagni et al., 2022, pp. 810–1823) we did not specifically predict whether autistic participants' age-related differences in PM would run in parallel, converge with or diverge from those of the non-autistic participants. Finally, we correlated self-report measures of QoL with self-report and experimental measures of memory to explore the association between levels of prospective memory, QoL and older age in both non-autistic participants and non-autistic participants.

The present study forms part of a larger series of investigations of growing older in individuals with autism (Roestorf, 2018), and on whom background demographic, IQ and QoL data were already available. The 57 participants for whom PM data are reported here were an opportunity subset of these who were available to undergo the experimental measures of EBPM and TBPM and to take the questionnaire measures of PM, RM and QoL. Given the wide range of data available to the participants of the present study, in order to avoid detecting false positive findings by chance, we limited our analysis to a consideration of Overall and Health-related QoL and the memory measures reported here. Because of this relatively small sample size our aims were limited establishing a preliminary impression of the relations between PM and QoL that would form a basis for further research.

3. Ethics

This study formed part of a larger project titled *Age-Related Effects on Cognition and Quality of Life in Adults with Autism Spectrum Disorder* for which ethical approval was granted by the City, University of London Psychology Department Research Ethics Committee (ref: PSYETH(UPTD) 13/14 28).

4. Method

4.1. Participants

Fifty-seven adults (35 autistic, 22 non-autistic) were selected from a larger group of 87 participants who took part in a series of longitudinal cross-sectional studies (Roestorf et al., 2022; Yarar et al., 2022) on growing older with autism. The sample size for this study was determined by our ability to recruit as many as we could age-matched autistic and non-autistic participants who were available to carry out the experimental tasks within the time available. All the autistic participants had a formal diagnosis of autism, confirmed by a copy of clinical diagnostic reports obtained at enrolment. The ADOS was administered to 47 participants (82.5%) in the ASD group at an earlier point in the longitudinal study. About one-third (36.2%) of these met the Total Scores cut-off for Autism and about one-third (36.2%) met the cut-off for Autism Spectrum leaving just less than one-third (27.7%) who did not meet either cut-off. On the Communication index, the majority of these participants (53.2%) met the cut-off for Autism and more than one-third (38.3%) met the cut-off for Autism Spectrum Disorder. Only 4 participants (8.5%) did not meet the minimum cut-offs. On the Social Interaction index, approximately half of ASD participants met the cut-off for Autism and more than one-third (38.3%) met the cut-off for Autism Spectrum Disorder. Only 4 participants (8.5%) did not meet the minimum cut-offs for Communication and Social Interaction, respectively and only 2.8% of individuals were below threshold for Total scores.[3]

Participants ranged in age from 23 to 80 years (Autistic $n = 35$, mean age 47.34 years, SD 14.13; Non-Autistic $n = 22$, mean age 53.20 years, SD 16.73; see Table 1 for further details). The relative lack of studies on ageing in autism when the study was planned meant there was no consensus on the definition of 'older' age in this group and in the present study we defined 'older' adults as those aged ≥50 years and 'younger' adults as those aged 18–49 years (see Bowler, Geurts, & Howlin, 2019 for further discussion of the meaning of 'older' in the context of autism).

Participants were matched between Diagnostic Group (Autistic vs Non-Autistic) and Age Group (Older vs Younger) on age and number of years of formal education. There were fewer females than males in the sample but the distributions were similar in the non-autistic and autistic participants in each age group (Max. χ^2 (1) = 2.18, Min. $P = .14$) and in the older and younger participants in each diagnostic group (all χ^2

[3] Because of the sample size, the data did not always meet the assumptions for parametric statistics (see Results section) all analyses are supplemented by Bayesian statistics. In contrast to classical, frequentist statistical techniques, which offer a binary assessment of significant or non-significant effects with a significance level of $P < .05$, Bayes Factors represent the ratio of the likelihood of the reported data given the experimental hypothesis vs its likelihood given the null hypothesis (BF_{10}). BF_{01} represents the inverse of that, i.e. the ratio of the likelihood of the data given the null hypothesis versus its likelihood given the experimental hypothesis. By convention, BF_{10} values > 3 represent substantial evidence for H_1 and $BF_{10} < .3$ as substantial evidence for H_0 (Lee & Wagenmakers, 2014).

Table 1 – Age and psychometric data for old and young autistic and non-autistic participants.

Measures	Non Autistic			Autistic			Autistic + Non Autistic		
	Young (n = 10)	Old (n = 12)	Young + Old	Young (n = 18)	Old (n = 17)	Young + Old	Young	Old	Young + Old
Age (years)	37.66 (8.06)	66.15 (8.87)	53.20 (16.73)	35.47 (7.35)	59.96 (6.23)	47.37 (14.13)	36.25 (7.54)	62.52 (7.92)	49.61 (15.31)
Gender (m:f)	6:4	6:6	12:10	15:3	13:4	28:7			
Years of Education **SRS** *Constantino*	15.20 (1.81)	13.50 (2.81)	14.27 (2.51)	15.44 (2.66)	15.00 (2.92)	15.23 (2.76)	15.36 (2.36	14.38 (2.92)	14.86 (2.68)
Total	47.25 (5.97) [a]	45.25 (3.69) [b]	46.25 (4.21)	71.47 [c] (8.70)	74.79 (12.41)	72.97 (10.49)	63.72 (13.92)	64.05 (17.65)	63.87 (15.60)
SCI	47.38 (5.78) [a]	45.75 (3.99) [b]	46.56 (4.87)	69.76 [c] (8.58)	74.21 (12.50)	71.77 (10.58)	61.60 (12.13)	63.86 (17.27)	63.19 (15.05)
RRB	48.00 (5.53) [a]	44.50 (4.75) [b]	46.25 (5.30)	75.24 [c] (10.67)	73.29 (10.89)	7.35 (10.64)	66.52 (15.9)	62.81 (16.79)	64.79 (16.25)
WAIS IQ									
Full-Scale IQ	115.75 (9.63) [a]	112.10 [b] (13.35)	113.72 (11.67)	111.29 [c] (18.84)	116.94 (15.17)	114.12 (17.09)	112.72 (16.38)	115.15 (15.88)	113.98 (15.31)
Verbal IQ	114.50 (9.55) [a]	113.70 [b] (9.37)	114.06 (9.17)	111.29 [c] (14.58)	116.4 (12.38)	113.88 (13.58)	112.32 (13.07)	115.44 (11.25)	113.94 (12.14)
Perc. Reasoning	115.50 (9.13) [a]	110.30 [b] (15.89)	112.61 (13.23)	110.06 [c] (19.37)	114.7 (15.21)	112.31 (17.31)	116.8 (16.77)	113.77 (15.31)	112.46 (15.88)
Working Memory	111.75 (13.54) [a]	104.70 [b] (14.70)	107.83 (14.25)	111.29 [c] (19.08)	115.4 (16.07)	113.38 (17.50)	111.44 (17.21)	111.48 (16.18)	111.46 (16.52)
Processing Speed	106.75 (13.92) [a]	104.40 [b] (14.30)	105.44 (13.76)	101.82 [c] (21.46)	105.35 (12.14)	103.59 (17.26)	103.4 (19.21)	105.00 (12.72)	104.23 (16.02)

[a] N = 8.
[b] N = 10.
[c] N = 17.

(1) < 1.0). Frequentist and Bayesian Diagnostic Group by Age Group ANOVAS on Chronological Age revealed a significant effect for Age Group ($F(1,53) = 167.03$, $P < .001$, $\eta^2_P = .76$, BF_{incl}[4] $= 6 \times 10^{14}$) but not for Diagnostic Group ($F(1,53) = 4.17$, $P = .05$, $\eta^2_P = .073$, $BF_{incl} = 1.83$) and no interaction between Age Group and Diagnostic Group ($F(1,53)$, 1, *n. s.*, $BF_{incl} = 1.94$). A similar comparison of the older and younger participants within Diagnostic Groups' number of years of education yielded no significant main effects or interactions (Max. $F(1,53) = 2.20$, Min. $P = .144$, Max. $\eta^2_P = .3$, Max. $BF_{incl} = .95$). Similar analyses of scores on the *Social Responsiveness Scale* (SRS, Constantino & Gruber, 2012) revealed significant differences between diagnostic groups on the Total SRS score ($F(1,43) = 91.80$, $P < .001$, $\eta^2_P = .681$, $BF_{incl} = 2.23 \times 10^9$), the Social Communication Index score ($F(1,43) = 82.32$, $P < .001$, $\eta^2_P = .657$, $BF_{incl} = 3.73 \times 10^8$) and the Restricted and Repetitive Behaviours score ($F(1,43) = 95.00$, $P < .001$, $\eta^2_P = .688$, $BF_{incl} = 1.26 \times 10^{10}$). For these last four variables neither the main effect for Age Group or nor the Age Group by Diagnostic Group interaction was significant (Max. $F = 2.20$, min p .144, Max. $\eta^2_P = .04$, Max. $BF_{incl} = .95$).

And finally, neither Full-scale IQ (FSIQ); Verbal Comprehension (VCI); Perceptual Reasoning (PRI); Working Memory (WMI); Processing Speed (PSI) index scores from the Wechsler Adult Intelligence Scale (WAIS-IV, Wechsler, Coalson, & Raiford, 2008) showed any main or interaction effects for Age Group or Diagnostic Group (Max. $F(1,48) = 1.34$, min p .253, Max. $\eta^2_P = .03$, Max. $BF_{incl} = .38$).

4.2. *Memory and quality of life measures*

Participants were administered self-report questionnaire measures of PM RM and quality of life as well as experimental measures of event-based and time-based PM.

4.2.1. *Prospective and retrospective memory questionnaire (PRMQ; Smith, Sala, Logie, & Maylor, 2000; Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Crawford, Henry, Ward, & Blake, 2006)*

The PRMQ is a reliable (Crawford et al., 2006) 16-item self-rated questionnaire designed for use with respondents ranging in age from 18 to 93 years. It addresses everyday memory slips and errors in future planned intentions (8 items) and past memory content (8 items). Its ecological validity has been demonstrated in differentiating performance difficulties in the PM and RM components of everyday prospective remembering (Kliegel & Jäger, 2006). Participants are asked to rate the frequency of difficulties on an average day (scale 1 (never) to 5 (very often)). Here, raw scores were used for prospective (PRMQ-PM) and retrospective (PRMQ-RM) memory components, with lower scores indicating fewer memory difficulties.

[4] Similarly to BF_{10}, BF_{incl} indicates whether the data are more likely when an effect is included in the model compared to when it is excluded.

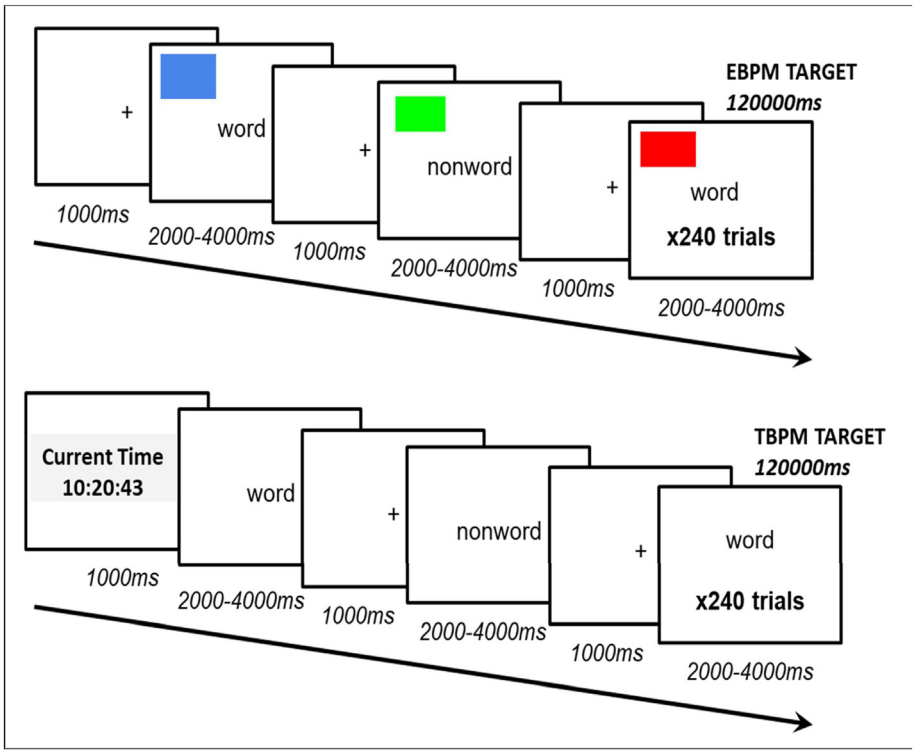

Fig. 1 – Schematic of the laboratory-based EBPM (event-based prospective memory) and TBPM (time-based prospective memory) tasks.

4.2.2. *Laboratory-based experimental tasks (EBPM and TBPM)*

In line with many other studies in the area (see Landsiedel et al., 2017), both the EBPM and TBPM tasks used here were embedded in ongoing, computerised lexical decision tasks in which participants had to judge whether 240 sequentially presented letter sequences were words or nonwords (Walter & Meier, 2014; Williams, Jarrold, Grainger, & Lind, 2014). Further details of stimulus selection and task construction can be found in Appendix 1.

4.2.3. *Procedure for laboratory-based experimental tasks (EBPM and TBPM)*

4.2.3.1. Ongoing lexical decision task. The laboratory EBPM and TBPM paradigms were equated for complexity of the ongoing tasks, procedure, frequency of stimuli (presentation rates), demands of the PM task (aside from the obvious PM cue and action differences), PM target times, and the task duration. The schematic organization of the two tasks is set out in Fig. 1. The order of EBPM and TBPM tasks was systematically counterbalanced to avoid the effects of biased performance by task type. A starting central fixation cross was set to a duration of 1000 ms; the fixation cross also appeared briefly between trials (1000 ms; adjusted). The words and nonwords were presented in the centre of the screen, one at a time in random order, and in a single block of 240 trials (120 words; 120 nonwords). Using a standard keyboard, participants were instructed to press 'w' for words and 'n' for nonwords (Boywitt, Rummel, & Meiser, 2015; Kliegel, Martin, McDaniel, & Einstein, 2001). All lexical items appeared in lowercase black font (Courier New, 18 pt.). The presentation rate was either (2000 ms (ms), 3000 ms or 4000 ms; mean 3000 ms; see Fig. 1). This stopped participants using precise timing of stimulus intervals as an additional cue to the PM task, which would potentially have biased task performance. The fixation duration between trials (inter-trial stimulus interval) was automatically adjusted between trials to ensure consistency of presentation and trial duration between participants. Thus, if a participant took slightly longer to make a response on one trial, the presentation of the inter-trial stimulus interval was reduced so that the next trial could be presented. The PM-ongoing task lasted 12 min.

4.2.3.2. Event-based prospective memory (EPBM) task. In the EBPM task, a small, coloured box was presented simultaneously in the top left corner of the screen, accompanying the presentation of each word and nonword. The colour of the box was pseudo-randomised: blue, green, magenta, yellow, cyan, teal, lime, purple, or red (EBPM cue). For the PM action, participants were required to press '1' (PM action) when a red box was presented, before they made the 'w' or 'n' response in the ongoing task. There were seven EBPM opportunities and the PM outcome measures were *EBPMAcc* [hits (correct action)-false alarms (action at incorrect colour)], and response times (*EBPMRT*) in milliseconds.

4.2.3.3. Time-based prospective memory (TBPM) task. In the TBPM task, participants were shown an on-screen digital clock (actual time of day) at the start of the task and were instructed to make a mental note of the time. Participants could access the on-screen clock at any point, as frequently as they wished by pressing 'C' to check the current clock time. The time was displayed for1000 ms before returning to the word/nonword

Table 2 – Mean Overall and Health-related QoL for older and younger autistic and non-autistic groups.

	Overall QoL							
	Non Autistic			Autisitic			Non Autistic + Autistic	
	Young	Old	Young + Old	Young	Old	Young + Old	Young	Old
Mean	4.22	4.13	4.18	3.25	3.62	3.41	3.60	3.81
s.d.	.67	.35	.53	.86	.77	.82	.91	.68
n	9	8	17	16	13	29	25	21
	Health QoL							
	Non Autistic			Autistic			Non Autistic + Autistic	
	Young	Old	Young + Old	Young	Old	Young + Old	Young	Old
Mean	4.11	3.38	3.76	3.12	3.00	3.10	3.52	3.14
s.d.	.33	1.51	1.09	1.05	1.00	1.01	.96	1.92
n	9	8	17	16	13	29	25	21

item. As in the lab-EBPM task, participants made word (press 'w') or nonword (press 'n') judgments as part of the ongoing task. The TBPM action was to press the space bar at 2-min intervals. to log their time during the six TBPM opportunities in the ongoing task. Performance measures followed previous studies of TBPM (Williams et al., 2014) as follows. *TBPMAcc* was measured as the proportion of correct TBPM responses, within a prescribed window, 20s before or 20s after target times. Responses outside this time window were not counted. We acknowledge that this 40 s window represents 33.33% of the 120 s interval but we would argue that this is a reasonable compromise measure of participants' capacity to follow an instruction to repeat a specific response at regular intervals in the absence of an explicit external cue. When we coded the data using strict (± 10 s) and lenient (± 60 s) windows, the strict window resulted in 8% accuracy in the non-autistic population and 18 % in the autistic group – close to a floor effect. The lenient criterion resulted in ceiling performance in the non-autistic and 95% accuracy in the autistic participants.[5] *TBPMProp*. The number of times a participant pressed the space bar divided by six, the maximum possible number of times this could be made (Williams et al., 2014. *TBPMCC*. The number of times a participant checked the clock during the experiment (Groenman et al., 2024).

4.2.4. *World Health Organisation quality of life, short form (WHOQOL-BREF; World Health Organization, 1996)*

The WHOQOL-BREF was administered to all participants as part of a larger study (see Roestorf et al., 2022). It contains 26 items related to the four domains: Physical, Psychological, Social and Environmental, each of which is self-rated on a Likert-type scale, from 1 (worst) to 5 (best), with slight variations in response naming conventions. We applied a conversion formula (see International Well-being Group, 2013) to WHOQOL-BREF scores to yield Overall-QoL and Health-QoL to use as dependent variables here. The appropriateness of the WHOQOL-BREF for the study of autism generated a great deal of debate (see Ayres et al., 2018; Simpson et al., 2024), which has now led to the development of a more autism-appropriate measure (the ASQoL, McConachie et al., 2018) designed to be used alongside the WHOQOL-BREF (Rodgers, 2022). When the larger study of which this is a part was designed, the ASQoL was not available, and the decision was made to employ the WHOQoL-BREF, both because it was widely-used measure in autism research at that time and because it is had acceptable psychometric properties for the larger sample (n = 136, Yarar et al., 2022) from which the present sample was drawn.

5. Results

5.1. *Preliminary checks on homogeneity of variance and normality of distributions*

Levine's test of Homogeneity of Variance for the EBPM and TBPM measures showed none of the variables reported here violated this assumption (Max. Levene's statistic .904, d. f. = 1.52, Min. P = .33). Table S1 in the supplementary materials shows that almost all the variables were non-normally distributed according to the Kolmogorov–Smirnov and Shapiro–Wilk tests. For this reason, where possible, non-parametric analyses (z-scores from the Mann–Whitney test) were used, which were supplemented by Bayesian analyses computed using JASP (JASP Team, 2023). Because our use of chronological age as a categorical variable results in some loss of information, in the following sections we supplement the design-based analyses with exploratory correlations[6] and associated Bayes factors between chronological age and the experimental and questionnaire measures of memory and quality of life.

5.2. *Quality of life*

To see if our sample showed similar patterns of age- and autism-related differences in QoL, set out in Table 2 are Mean Overall QoL and Health QoL scores for the four groups of participants The two measures were found to intercorrelate significantly positively for the autistic (r_p = .55, P = .005,

[5] We thank an anonymous reviewer for drawing this point to our attention.

[6] In line with the previous point, we considered using Kendall's *Tau* for correlations but because it is not appropriate for statistical comparison of the size of correlation coefficients, we used Pearson's r (r_p) instead.

BF_{10} = 20.14) but not the non-autistic (r_p = .29, P = .25, BF_{10} = .55) participants, a difference in correlations that was not significant (z = .94, P = .34). To test our first prediction of poorer QoL in the autistic participants, we carried out separate 2 (Diagnostic Group) x 2 (Age Group) ANOVAS for each of these measures. These analyses showed that autistic participants had poorer Overall and Health QoL although the latter, while being statistically significant, had a low Bayes Factor (Overall QoL: $F(1,42)$ = 10.91, P < .005, η^2_P = .21, BF_{incl} = 23.97; Health QoL: $F(1,42)$ = 4.17, P < .05, η^2_P = .09, BF_{incl} = 1.69). For neither measure was there an Age main effect or an Age x Diagnostic Group interaction (Max. $F(1,42)$ = 2.11, Min. P > .154, Max. η^2_P = .05, Max. BF_{incl} = .55), a pattern that was confirmed by correlational analysis (Max. r_p = −.37, Min P = .14, Max. BF_{10} = .83).

5.3. PRMQ self-reported difficulties in everyday memory

To test the predictions centred on age- and diagnosis-related differences in memory, we first carried out a series of frequentist and Bayesian mixed 2 (Diagnostic Group) x 2 (Age Group) x 2 (Memory Type) repeated measures ANOVAs were used to compare differences between Diagnostic Groups and Age Groups on the self-report measures of difficulties measured by the PRMQ PM and PRMQ RM. These data, set out in Table 3, show higher levels of everyday PM-related difficulties (higher raw scores) in the younger and older autistic groups compared with the corresponding non-autistic groups. A repeated measures ANOVA revealed a significant main effect for Diagnostic Group ($F(1,51)$ = 16.17, P < .001, η^2_P = .24, BF_{incl} = 82.77) and Memory Type ($F(1,51)$ = 16.54, η^2_P = .25, BF_{incl} = 105.88) robustly reflecting fewer reported difficulties by the non-autistic group, and fewer retrospective rather than prospective memory difficulties across both diagnostic groups. No other main effects or interactions were significant (Max. $F(1,51)$ = 2.29, Min. P = .137, Max. η^2_P = .04, Max. BF_{incl} = .73) leading to the conclusion that both diagnostic groups reported fewer retrospective than prospective memory difficulties and that overall reported memory difficulties (prospective and retrospective) were greater in the autistic than in the non-autistic group. The absence of an Age Group main effect was confirmed by a correlational analysis between age And the two PRMQ scores (Max. r_p = .14, Min. P = .49, Max. BF_{10} = .30, this last figure providing moderate evidence in favour of the null hypothesis. PRMQ PM and PRMQ RM scores correlated highly in both the non-autistic (r_p) = .61, P < .001, BF_{10} = 19.4) and the autistic (r_p = .68, P < .001, BF_{10} = 1983.05) participants.

5.4. Laboratory-based prospective memory tasks

5.4.1. Ongoing tasks

Set out in Tables 4A and 4B are the corrected hits and reaction times for the lexical decision tasks in which the Event-Based and Time-Based PM tasks were embedded. Inspection of the tables shows near ceiling hit rates in all participants, which was confirmed by separate frequentist and Bayesian 2 (Diagnostic Group) x 2 (Age Group) ANOVAs, which did not reveal any significant main effects or interactions (Max. $F(1,53)$ = 1.99, min P = .16, Max. η^2_P = .16, Max. BF_{incl} = .47). The RT data, by contrast showed a significant age-related slowing of RT for both Diagnostic groups for the ongoing task associated with the EBPM task (Age Group: $F(1,53)$ = 18.81, P < .001, η^2_P = .262, BF_{incl} = 329.76), which was confirmed by correlational analysis (EBPM: Non-Autistic r_p = .62, P < .005, BF_{10} = 164.51; Autistic r_p = .59, P < .001, BF_{10} = 145.3. TBPM: r_p = .49, P < .02, BF_{10} = 3.224; Autistic r_p = .19, P < .15, BF_{10} = .234.

5.4.2. Event-based prospective memory (EBPM) task

The accuracy (EBPMAcc) and response times (EBPMRT) for the four participant groups' performance on the EBPM task are set out in Table 5A. Separate Diagnostic Group x Age Group ANOVAs for these data showed no significant main effects or interactions for the EBPMAcc data (Max. $F(1,52)$ = 1.12, min P > .296, Max. η^2_P = .02, Max. BF_{incl} = .45). For the EBPMRT data, although there was no effect of Diagnostic Group ($F(1,52)$ < 1, n. s. BF_{incl} = 1.24), there was a significant Age Group main effect ($F(1,52)$ = 8.77, P< .01, η^2_P = .144, BF_{incl} = 3.89) and a Diagnostic Group by Age Group interaction ($F(1,52)$ = 8.97, P< .01, η^2_P = .147, BF_{incl} = 4.90). *Post-hoc* Mann–Whitney tests showed that whereas younger autistic participants did not differ in RT from older ones, younger non-autistic participants were faster than older ones (z = 3.50 P < .001, d = .88,[7] BF_{10} = 20.52). When participants were compared across Diagnostic groups, older non-autistic participants were marginally slower than older autistic participants (z = 1.90, P < .06, d = .43, BF_{10} = 1.45), a difference that is significantly greater in the corresponding older and younger autistic participants (z = 2.59, P < .01, d = .60, BF_{10} = 2.03). Although these effects reach conventional levels of statistical significance (P < .05), the Bayes Factor values suggest that only one outcome measure (the difference in RT between younger and older non-autistic participants) offers no more than anecdotal support for the effect. Treating age as a continuous variable confirmed the finding of a significant age-related correlation with RT for the non-autistic (r_p = .71, P < .001, BF_{10} = 164.5) but not the autistic (r_p = .02, P = .90, BF_{10} = .22) participants, a difference between correlations that was significant (z = 2.97, P < .003).

5.4.3. Time-based prospective memory (TBPM) task

Data for the TBPM task are set out in Table 5B. As outlined earlier, the variables of interest here were TBPMAcc (Proportion of PM actions made in the time window ± 20s of target time), TBPMProp (Proportion of PM actions made out of the six possible opportunities)[8] and TBPMCC, the number of times a participant called up the clock. For each of these measures, 2 (Diagnosis) x 2 (Age Group) ANOVAs were carried out together with pairwise comparisons between Diagnostic Groups within Age Groups and between Age Groups within Diagnostic Groups in the case of significant interactions.

For the TBPMAcc data, this analysis showed no main effect for Age Group or Diagnostic Group (Max. $F(1,53)$ = .623, min P > .434, Max. η^2_P = .01, Max. BF_{incl} = .23 or for the Diagnosis x

[7] Rank biserial correlations are used as a measure of effect sizes in all Mann–Whitney analyses.

[8] The value of this variable can exceed 1, as participants can make more than six PM actions.

Table 3 – PRMQ raw scores (low score = fewer reported difficulties) for younger and older autistic and non-autistic participants.

		Non Autistic			Autistic			Autistic + Non Autistic		
		Young $n = 10$	Old $n = 12$	Young + Old $n = 22$	Young $n = 18$	Old $n = 16$	Young + Old $n = 34$	Young $n = 28$	Old $n = 28$	Young+ Old $n = 56$
PRMQ Prospective Memory.	**Mean**	18.40	18.42	18.41	24.39	22.80	23.67	22.25	20.85	21.56
	S.D	5.06	4.60	4.70	7.13	5.20	6.28	7.01	5.33	6.22
PRMQ Retrospect Memory.	**Mean**	15.30	16.00	15.68	20.78	22.13	21.39	18.82	19.42	19.11
	S.D	4.06	3.54	3.71	6.14	4.94	5.58	6.03	5.30	5.64

Table 4 – Hits and reaction times for the ongoing lexical decision task for both the Event-Based (A) and the Time-Based (B) experimental task.

A			Non Autistic			Autistic			Non Autistic + Autistic	
			Young ($n = 10$)	Old ($n = 12$)	Young + Old	Young ($n = 18$)	Old ($n = 17$)	Young +Old	Young	Old
	Hits	Mean	.96	.96	.96	.92	.94	.93	.94	.95
		S.D.	.03	.03	.03	.12	.09	.10	.10	.08
	RT (ms)	Mean	807	1025	926	834	1018	923	824	1021
		S.D.	134	202	203	144	187	189	139	190
B			Non Autistic			Autistic			Non Autistic + Autistic	
			Young ($n = 10$)	Old ($n = 12$)	Young + Old	Young ($n = 18$)	Old ($n = 17$)	Young + Old	Young	Old
	Hits	Mean	.98	.98	.98	.97	.97	.97	.97	.98
		S.D.	.02	.01	.02	.05	.03	.04	.04	.02
	RT (ms)	Mean	1001	1206	1113	1135	1227	1180	1087	1218
		S.D.	333	270	324	380	383	379	363	344

Table 5A – Accuracy and response times for the EBPM task.

A		Non Autistic			Autistic			Autistic + Non Autistic	
		Young ($n = 10$)	Old ($n = 12$)	Young + Old	Young ($n = 18$)	Old ($n = 16$)	Young + Old	Young	Old
Accuracy(E)	Mean	.73	.74	.73	.52	.73	.62	.59	.73
	S.D	.26	.31	.28	.55	.26	.46	.48	.28
RT (ms)	Mean	867	1295	1101	1082	1080	1081	1005	1172
	S.D	150	276	312	274	290	277	257	299

Table 5B – Accuracy and response times for d Accuracy, proportion of actions made and number of clock checks in the TBPM task.

B		Non Autistic			Autistic			Autistic + Non Autistic	
		Young ($n = 10$)	Old ($n = 12$)	Young + Old	Young ($n = 18$)	Old ($n = 17$)	Young + Old	Young	Old
TBPMAcc (Proportion of responses within ± 20s of target time)	Mean	.5	.26	.37	.38	.46	.42	.43	.37
	S.D	.49	.37	.43	.43	.42	.42	.45	.41
TBPMProp (Proportion of PM Actions Made)	Mean	.78	.53	.64	.72	.78	.75	.74	.68
	S.D	.28	.37	.35	.34	.39	.36	.32	.40
TBPMCC (number of times participant called up clock)	Mean	17.00	9.67	13.00	9.39	10.88	10.11	12.11	10.38
	S.D	7.64	8.12	8.57	6.28	8.15	7.18	7.62	8.01

Age Group interaction ($F(1,53) = 2.06$, $P = .16$, $\eta^2_P = .04$, $BF_{incl-} = .15$. A similar picture emerged from the analysis of the proportion of PM actions made (TBPMProp), with no significant main effects or interactions, Max. $F(1,53) = 2.66$, Min. $P > .11$, Max. $\eta^2_P = .05$, Max. $BF_{incl} = .37$).

The Clock Check (TBPMCC) data, showed no main effect either for Age Group or Diagnostic Group (Max. $F(1,53) = 2.44$, Min. $P > .124$, Max. $\eta^2_P = .04$, Max. $BF_{incl} = .60$ but the Diagnosis x Age Group interaction ($F(1,53) = 4.65$, $P < .04$, $\eta^2_P = .08$, $BF_{incl} = .74$) was significant although the Bayes factor did not suggest strong evidence for the interaction. Inspection of Table 4B shows that younger non-autistic participants made significantly more clock checks than older non-autistic participants ($z = 2.12$, $P = .04$ $d = .533$ $BF_{10} = 1.77$), this was not the case for the younger and older autistic participants ($z = .264$, $P = .79$, $d = .20$ $BF_{10} = .37$. This pattern of significant effects was confirmed by correlational analysis using age as a continuous variable. Whilst older non-autistic participants made fewer clock checks than younger ones ($r_p = -.64$, $P < .001$, $BF_{10} = 35.62$), this was not the case for the older and younger autistic participants ($r_p = .01$, $P = .59$, $BF_{10} = .24$) a difference between correlations that was significant ($z = 2.97$, $P < .005$). In addition, younger non-autistic participants also made significantly more clock checks than younger autistic ones ($z = 2.23$, $P < .03$ $d = .609$ $BF_{10} = 5.72$) but none of the other pairwise comparisons was significant (Max. $z = .74$, Min. $P = .66$, Max. $BF_{incl} = .38$).

5.5. *Correlations among QoL and memory measures*

To examine associations between measures of prospective memory and quality of life, we analysed separately for the two diagnostic groups relations among performance on the self-report measures of PM, RM and QoL together with the experimental measures of EBPM and TBPM listed in Tables 2, 4A and 4B. Inspection of the resulting correlations, set out in Table 6A, shows that within both autistic and non-autistic participant groups, apart from the effects already presented (the non-autistic group's negative age-related correlations with TBPMProp and TBPMCC and the significantly positive inter-correlation between the two self-report measures of memory (PRMQ PM and RM), there were no significant age-related correlations for either diagnostic group. Nor were there any significant correlations or elevated Bayes factors between the self-report memory measures and any of experimental measures of PM (Max. $r_p = -.23$, Min. $P = .30$, Max. $BF_{10} = .44$) for either diagnostic group. Overall QoL and Health QoL inter-correlated significantly with a strong Bayes factor for the autistic but not for the non-autistic group, a difference between the correlations that was not significant ($z = 1.07$, $p. = 29$).

Neither of the self-report (PRMQ) measures of PM or RM correlated significantly with Overall QoL scores for either diagnostic group (Max. $r_p = -.39$, Min. $P = .07$, Max. $BF_{10} = 1.20$) but Health QOL scores correlated significantly negatively with PRMQ RM for the non-autistic as well as for the autistic participants, a difference between the corelations that was not significant ($z = .72$, $P = .47$). Health QoL also correlated with PRMQ PM for the autistic but not the non-autistic participants, a difference between the corelations that was not significant ($z = .43$, $p. = .66$).

Only one of the experimental PM measures (TBPMCC) correlated positively with health QoL for the Non-Autistic group with the corresponding correlation for the autistic

Table 6A – Non autistic group.

		Age (years)	Overall Quality of Life	Health Quality of Life -	PRMQ Prospective Memory	PRMQ Retrospective Memory	EBPM RT	EBPM Accuracy	TBPMAccuracy	TBPMProportion of PM Actions
Overall Quality of Life	Pearson *r*	−.127								
	Sig. (2-tailed)	.627								
	N	17								
	BF_{10}	.334								
Health Quality of Life	Pearson *r*	−.374	.293							
	Sig. (2-tailed)	.139	.253							
	N	17	17							
	BF_{10}	.828	.548							
PRMQ Prospective Memory	Pearson *r*	−.111	−.298	**−.482***						
	Sig. (2-tailed)	.623	.245	.050						
	N	22	17	17						
	BF_{10}	.296	.560	1.775						
PRMQ Retrospective Memory	Pearson *r*	.080	−.374	**−.600***	**.612****					
	Sig. (2-tailed)	.723	.139	.011	.002					
	N	22	17	17	22					
	BF_{10}	.280	.826	5.986	19.438					
EBPM Response Time for PM actions	Pearson *r*	**.711****	.085	−.109	−.066	−.102				
	Sig. (2-tailed)	<.001	.745	.676	.770	.652				
	N	22	17	17	22	22				
	BF_{10}	161.513	.315	.325	.275	.291				
EBPM Accuracy	Pearson *r*	.001	.084	−.283	−.001	.149	−.228			
	Sig. (2-tailed)	.996	.750	.270	.996	.509	.308			
	N	22	17	17	22	22	22			
	BF_{10}	.264	.314	.526	.264	.324	.431			
TBPM Accuracy	Pearson *r*	−.346	**.582***	.417	−.233	−.219	−.292	.046		
	Sig. (2-tailed)	.115	.014	.096	.296	.328	.188	.838		
	N	22	17	17	22	22	22	22		
	BF_{10}	.852	4.818	1.084	.442	.415	.597	.269		
TBPMProportion of PM actions	Pearson *r*	**−.529***	.054	.456	−.027	−.390	−.203	.028	.332	
	Sig. (2-tailed)	.011	.838	.066	.904	.073	.365	.901	.131	
	N	22	17	17	22	22	22	22	22	
	BF_{10}	5.341	.305	1.432	.266	1.201	.388	.266	.772	
TBPM Total Clock Checks	Pearson *r*	**−.644****	.293	.421	−.118	−.180	−.377	.011	.277	.252
	Sig. (2-tailed)	.001	.254	.092	.600	.424	.084	.961	.211	.258
	N	22	17	17	22	22	22	22	22	22
	BF_{10}	35.615	.547	1.114	.301	.357	1.078	.264	.551	.483

BF_{10} > .3 or >3.0 in *italics*.
Non-Autistic Participants.
** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

group being non-significant, a difference between the correlations that was not significant ($z = .53$, $p. = .13$).

6. Discussion

The study partly fulfilled its overall aim, which was to fill a gap in the literature by establishing whether some of the existing measures of PM can predict reported overall and health-related QoL in non-autistic and autistic individuals in the context of advancing age in later adulthood. Many of the findings replicated earlier work but it is also noteworthy that there were many instances where there were no age- or diagnosis-related effects, indicating that neither older age nor autism appeared to adversely affect memory or QoL in our sample. However, closer consideration of these overall findings highlights important methodological and conceptual issues that need to be addressed when designing future investigations.

Our finding of poorer overall and health-related QoL in the autistic participants is consistent with many, but not all previous studies (Ayres, et al., 2018; Lin et al., 2024; Roestorf et al., 2022;[9] van Heijst & Geurts, 2015; Yarar et al., 2022[7]) but our finding of moderate evidence that neither overall QoL nor health-related QoL change over the wider adult life span in either in either diagnostic group is qualified by the small sample sizes and the magnitude of the Bayes Factors both of which prompt caution in interpreting these null results. As was also predicted, older participants in both diagnostic groups reported significantly more PM and RM difficulties than younger ones although the higher levels of PM than RM difficulties reported by the autistic and the non-autistic groups was not predicted. These results mirror earlier studies of younger autistic adults (Charlton, McQuaid, Lee, & Wallace, 2023; Williams, et al., 2014), which also found poorer self-reported PM and RM performance in autistic participants. The patterning of our PM and RM findings and those of the other studies contrasts with what is reported in other domains such as general cognition, executive function or subjective memory complaints where older autistic individuals were found to report greater levels of difficulty than did older non-autistic individuals (Kenny, Remington, and Pellicano, 2024; Geurts, Pol, Lobbestael, & Simons, 2020; Kenny, et al. (2024); Klein, McQuaid, Charlton, Klinger, & Wallace, 2022; Lever & Geurts, 2016; Torenvliet et al., 2023). These differences between studies and across measures could have resulted from, for example, sample sizes or recruitment, gender composition of the samples, which ranged widely between studies from 17 (14 males; Williams et al., 2014) to 350 (50% male; Charlton et al., 2023), all of which are factors that could usefully be addressed in future investigations. Nevertheless, our findings clearly demonstrate that both the older and younger autistic individuals in the present study were as capable as age-matched non-autistic individuals of reporting their own inner life experiences and possessed similar levels of awareness of the difficulties they experienced (see also Kenny et al., in press for a more qualitative reflection on this point).

The performance by all participants on the ongoing task in which the experimental EBPM and TBPM tasks were embedded was near ceiling, replicating what is seen in the majority of previous studies of PM autistic children (Faustmann, Kretschmer-Trendowicz, & Altgassen, 2022; Williams et al., 2013, 2014) and strengthens our confidence in the participants' engagement with and performance on these tasks. The results partially support our prediction that older autistic adults would perform less well on a TBPM than on an EBPM task. Moreover, our confidence in the finding that older age differentially affected the two diagnostic groups' management of their clock checking behaviour (TBPMCC) is also strengthened by the absence of significant main or interaction effects for either response accuracy (TBPMAcc) or for proportion of PM events performed (TBPMprop), making it unlikely that participants had difficulties with memorising the requirements of the PM task (Marsh & Hicks, 1998). The diminished TBPMCC performance of the younger autistic compared to younger non-autistic participants (Table 5B) also supports our prediction that age would affect TBPM more than EBPM in the autistic participants and although we made no specific hypothesis regarding the patterning of any age-related differences on the PM tasks, the age-related reduction in the proportion TBPM clock checks, seen only in the non-autistic participants (Table 6B), suggests that age-related differences in this particular measure appear to follow a 'protected' rather than a 'parallel' or 'double jeopardy' age-related reduction in performance similar to that reported in many other studies (Geurts & Vissers, 2012; Lever & Geurts, 2016; Ring, Gaigg, & Bowler, 2016; Roestorf et al., 2019; Yarar et al., 2022), which is more likely in cross-sectional studies like this one, and may result from factors such as compensation or cohort effects (Torenvliet et al. (2023). These issues need to be addressed in future studies.

It is possible that the autistic participants' reduced TBPMCC scores resulted from the combined requirement to recall the intended action and then to switch attention either to an inner representation of elapsed time or to an external signal (the on-screen clock) rather than the memory component of TBPMCC. Attentional disengagement and switching are known to be difficult for autistic individuals (Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Kenworthy, Yerys, Anthony, & Wallace, 2008; Leung and Zakzanis, 2014; Yerys et al., 2009 but see Geurts, Corbett, & Solomon, 2009) and may also underlie their poor performance on specific measures extracted from experimental TBPM tasks, such as the TBPMCC measure used here. Reduced TBPMCC scores may also have resulted from the autistic participants' difficulties with judging elapsed time (Isaksson et al., 2018) or their more general difficulties with temporal aspects of cognition (Casassus et al., 2019; Jurek et al., 2019, see also Hinault, et al., 2023).

The absence of significant correlations between the, PRMQ and the experimental tasks despite both purporting to be memory measures, mirrors findings of many existing studies of older non-autistic (Gryffydd, Mitra, Wright, & Kinsella, 2022;

[9] There is substantial participant overlap between Roestorf et al.'s and Yarar et al.'s studies and the present one.

Table 6B – Autistic group.

		Age (years)	Overall Quality of Life	Health Quality of Life -	PRMQ Prospective Memory	PRMQ Retrospective Memory	EBPM RT	EBPM Accuracy	TBPM Accuracy	TBPMProportion of PM Actions
Overall Quality of Life	Pearson *r*	.182								
	Sig. (2-tailed)	.345								
	N	29								
	BF_{10}	.353								
Health Quality of Life	Pearson *r*	−.062	**.546****							
	Sig. (2-tailed)	.750	.002							
	N	29	29							
	BF_{10}	.242	20.140							
PRMQ Prospective Memory	Pearson *r*	−.120	−.133	**−.595****						
	Sig. (2-tailed)	.504	.510	.001						
	N	33	27	27						
	BF_{10}	.268	.294	38.859						
PRMQ Retrospective Memory	Pearson *r*	.135	−.026	**−.436***	**.682****					
	Sig. (2-tailed)	.453	.898	.023	<.001					
	N	33	27	27	33					
	BF_{10}	.284	.421	2.798	1983.05					
EBPM Response Time for PM actions	Pearson *r*	.024	.215	.184	.086	.312				
	Sig. (2-tailed)	.895	.272	.349	.641	.082				
	N	34	28	28	32	32				
	BF_{10}	.215	.421	.356	.244	.937				
EBPM Accuracy	Pearson *r*	.241	−.109	−.007	−.123	−.159	−.191			
	Sig. (2-tailed)	.170	.582	.973	.504	.385	.280			
	N	34	28	28	32	32	34			
	BF_{10}	.527	.271	.235	.272	.316	.373			
TBPM Accuracy	Pearson *r*	.031	−.175	**−.378***	.069	.001	−.241	.268		
	Sig. (2-tailed)	.859	.364	.043	.704	.996	.170	.125		
	N	35	29	29	33	33	34	34		
	BF_{10}	.214	.342	1.616	.232	.217	.526	.658		
TBPMProportion of PM actions	Pearson *r*	.203	−.241	.052	.062	−.038	−.138	.172	.273	
	Sig. (2-tailed)	.241	.208	.790	.732	.833	.436	.331	.113	
	N	35	29	29	33	33	34	34	35	
	BF_{10}	.407	.491	.239	.229	.221	.286	.336	.704	
TBPM Total Clock Checks	Pearson *r*	.095	−.014	−.045	.059	.094	−.327	.305	.187	.164
	Sig. (2-tailed)	.587	.943	.818	.743	.604	.059	.080	.281	.347
	N	35	29	29	33	33	34	34	35	35
	BF_{10}	.242	.231	.237	.228	.246	.174	.933	.368	.322

BF_{10} > .3 or >3.0 in *italics*.
Autistic Participants.
** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Kliegel & Jäger, 2006) and autistic participants (Groneman et al., 2024), who report at best marginally significant associations when comparing PRMQ scores with clinic-based 'breakfast-type' tasks or lab-based PM tasks. This contrast between self- or other-report measures and more direct, experimental measures of memory (including PM) and a range of other cognitive processes is widely reported Raskin, Shum, Ellis, Pereira, & Mills, 2018; see Kenworthy et al., 2008; Kenny et al., 2024 for a discussion in relation to the assessment of executive functions in autism). The consensus of discussions about what are the most appropriate measures to use when quantifying PM (Blondelle, Hainselin, Bounden, & Quaglino, 2020; Blondelle, Sugden, & Hainselin, 2022; Hainselin, Gounden, & Blondelle, 2021; Henry, 2021a, 2021b; Thompson, Henry, Rendell, Withall, & Brodaty, 2015) is that self-report and experimental PM measures have poor convergent validity resulting from a wide range of factors that include different self-report measures tapping different aspects of PM (Sugden Thomas & Kiernan, 2021), the specific psychological processes involved in PM tasks, e.g. attention, short-term and long-term memory, executive functions (McDaniel & Einstein, 2000), task procedures such as event-based or time-based cues (Einstein & McDaniel, 1990; Einstein et al., 1995), whether the future action is self- or other-generated (Woods Dawson, Wever et al., 2009). Authors such as Sheppard et al. (2018) have argued for detailed analyses of the task demands of the PM tasks. The question of whether or not performance on indirect, questionnaire measures or direct, lab-based measures can predict actual PM performance in real-life adds to this complexity, and even if a satisfactory resolution of this complexity were possible (see Blondelle, Hainselin Gounden & Quaglino, 2020; Blondelle et al., 2022; Hainselin et al., 2021; Henry, 2021a, 2021b for further discussion), adapting any solution to a neurodiverse population such as autism adds a further dimension to the problem. In particular, we cannot automatically assume that a questionnaire measure or lab-based procedure shown to be a valid predictor of PM 'in the field' in one population (e.g. older neurotypical individuals) would necessarily be so for an autistic population. The TBPMCC findings from the present study are a good illustration of how the autistic participants responded in particular ways to a lab-based measure of TBPM, reflecting Mottron and colleagues' argument that autism researchers need to be mindful of the autism-appropriateness of measurement instruments that were developed in the context of a 'neurotypical', non-autistic population (Mottron, 2004; Mottron, Dawson, & Soulières, 2008).

Such critical reflections should also be applied to identification of potential, systematic sources of autism-specific difference triggered by the QoL questions such as was used by McConachie et al. (2018) in their development of the ASQoL, an autism-appropriate measure of QoL The points made in the last paragraph also affect conclusions about the diagnostic differences in correlations between PM and QoL we observed and which are set out in Tables 6A and 6B. These differences may reflect autism-specific processes in PM task performance interacting with the instruments used to measure QoL in particular ways (see Simpson et al., 2024). Or they may reflect autistic people's acute awareness of difficulties in their everyday lives (Henninger & Taylor, 2013; Scheeren, Howlin, Pellicano, Magiati, & Begeer, 2022) making them likely to choose the 'difficulty option' in any instrument that directly or indirectly asks them about problematic issues whether they be memory or QoL or some other aspect of their lives. Similar conclusions to these were drawn by Yarar et al. (2022) from their observation that depression was a strong predictor of QoL in older autistic individuals.

Although the conclusions of present study are constrained by the small sample size, which limited statistical power and ruled out more complex statistical analyses[10], we tried to overcome this by restricting our aims, and consequently the number of statistical analyses. We also used Bayes factors to help quantify the extent to which our data supported inferences of difference or no difference or were inconclusive. A further limitation is the relatively young age of our older samples resulting in our having to define 'old' as 50 years of age or older and the absence of very old participants from our sample (we were able to recruit only five participants over the age of 70 years) may have limited the likelihood of finding age-related effects in our analyses. Nor did our sample include individuals with co-occurring neurodevelopmental conditions or cognitive disabilities, both of which are common in the autistic population (Simonoff et al., 2008; Soke, Maenner, Christensen, Kurzius-Spencer, & Schieve, 2018). Despite these limitations, we found limited evidence that self-report measures of PM and RM predict to some extent and individual's reported health-related QoL but that this association is not influenced either by age or by whether or not a person is autistic. Our findings also indicate that TBPM difficulties correlate with Health-Related but not Overall QoL. But perhaps most importantly, the findings show that the autistic participants may process the PM tasks and possibly the QoL questionnaire in a very different way from the non-autistic participants and that this difference might give us clues to what was driving the patterning of our findings. Future research should focus on.

The foregoing discussion highlights the need for pathways for future research to broaden its focus to encompass a wider range of research methods. As well as forensically unpacking the specific challenges and different response strategies that questionnaire measures and experimental procedures might engender in autistic individuals, investigators also need to develop more ecologically valid measures of PM in a way that acknowledges autistic difference and encompasses a broader, more complex vision of the autism spectrum (Pellicano et al., 2022) that demands a research strategy that includes more individualised, qualitative methods that should complement rather than supplant findings like those presented here.

Open Practices Statement

No part of the study procedure was pre-registered prior to the research being conducted. The datasets presented in this

[10] This study was part of a much larger investigation which included a wider range of measures. Here, we selected *a priori* only those variables that directly addressed the question of the potential association between PM and QoL.

article are not readily available because the raw data supporting the conclusions of this article are governed by General Data Protection Regulations (2008) in the EU and UK. Accordingly, no data, whether anonymised or identifiable, may be made shared without the express written consent of participants involved in this research. Requests to access the datasets should be directed to Amanda Roestorf (amanda.roestorf@autistica.org.uk).

CRediT authorship contribution statement

Amanda Roestorf: Writing – review & editing, Data curation, Conceptualization. **Dermot M. Bowler:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Sebastian B. Gaigg:** Writing – review & editing, Methodology. **Patricia Howlin:** Writing – review & editing, Supervision.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cortex.2025.01.006.

Appendix 1. Construction of the Lexical Decision Task

The words comprised letter strings (items) that formed standard recognisable words that varied in length (4–7 characters), number of syllables (1–4), and familiarity (low-high). The nonwords mimicked those rules just described, to give the appearance of words in that they were pronounceable and had a similar form in their construction of consonants and vowels. Each lexical decision task involved making judgements for 120 words and 120 nonwords. The lists contained equal numbers of 1, 2, 3 syllable words and nonwords, and equal numbers of items containing 4, 5, 6 or 7 letters (word length), which made up words/nonwords of one-syllable (for 4 letter items), or two-to four-syllables (for 5, 6, and 7 letter items). Words were sourced from the SUBTLEX-UK database (Duyck, Desmet, Verbeke, & Brysbaert, 2004) and nonwords were sourced from the WordGen databases (Van Heuven, Mandera, Keuleers, & Brysbaert, 2014). An initial search produced a cleansed data file which included word frequencies for 160,022 word types with corresponding Zipf-values: (values 1–3 = low frequency words; 4–7 = high frequency words). Item length was restricted to 4–7 characters since words less than 3 characters were mainly acronyms or very low frequency or multiple consonant letter strings (e.g. zzy), which were subsequently excluded. Further, words exclusions were those containing repetitive letters, apostrophes and hyphenation (e.g. zzzz, o'clock, non-British), as well as swear and emotionally salient words (e.g. anger, murder) and names (e.g. Adam, Mike). The resulting list comprised 3,694 words of 4–7 characters and 1–3 syllables in length, with frequencies ranging from 4.0 to 7.19 (low to high). Examples of words are: ARMY, BALL, MUSEUM, STATE, FLIGHT.

Because the SUBTLEX-UK database did not produce a comparable list of nonwords, the WordGen[11] tool was used to generate nonword items from actual words by combining up to 7 lexical rules, such as number of letters, lexical relatedness (neighbourhood size), word frequency and others (Boywitt et al., 2015; see also Rastle, Harrington, & Coltheart, 2002 for full description of lexicon methods). Nonword items from the WordGen tool comprised letter strings of vowels and consonants which were easily recognisable as nonwords, but pronounceable in one, two or three syllables of 4–7 characters, respectively. Examples of nonwords are: WABBY, MOOF. A final list of lexical items was created, and their order randomised to produce the task lists of 240 words (120 EBPM; 120 TBPM) and 240 nonwords (120 EBPM; 120 TBPM) for the lexical decision tasks. The rate of presentation (on-screen time for each item) was pre-randomised and fixed to words and nonwords, and the presentation order of items was randomised across trials and between participants.

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[11] The WordGen database incorporates properties of the CELEX and Lexique lexical databases, producing nonwords in English - Dutch, German, and French versions are also available; http://expsy.ugent.be/wordgen.htm; and see Boywitt et al., 2015. CELEX database: Baayen, Piepenbrock, & Gulikers (1995); and see Max Planck Institute for Psycholinguistics. http://celex.mpi.nl/. Lexique database: New B., Pallier C., Ferrand L., Matos R. (2001) A lexical database of contemporary French on the Internet: LEXICON, The Psychological Year, 101, 447–462. http://www.lexique.org.

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