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DOI
10.1002/aur.3195

Publication date
2024

Document Version
Final published version

Published in
Autism Research

Received: 18 December 2023 | Accepted: 23 June 2024

DOI: 10.1002/aur.3195

RESEARCH ARTICLE

Memory strategies in autistic and older adults

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Funding information
Netherlands Organization for Scientific Research, Grant/Award Number: 453–16-006

Abstract

Memory strategies in autistic adults seem to mimic strategies at older age, as both younger autistic and older non-autistic individuals use fewer semantic features in visual memory tasks. Therefore, the current study aims to investigate whether early differences in memory strategies lead to altered age-related effects in autism, particularly whether initial difficulties in strategy use become advantageous at older age (i.e., "protective aging"). A total of 147 participants across four groups (autistic younger/older, non-autistic younger/older) completed an online assessment. This assessment included a recognition version of the Visual Patterns Test (VPT) to evaluate semantic strategy use in visual memory, the Just Noticeable Difference (JND) size task for assessing visual processing, and the Multifactorial Memory Questionnaire to evaluate subjective memory functioning and strategy use (MMQ). Unexpectedly, all groups benefited from semantic features on the VPT, although the older groups performed less accurately and slower than the younger groups. The JND Size task showed no group differences. Autistic adults rated their MMQ memory as worse than non-autistic adults, despite reporting greater strategy use. These results indicate that cognitive strategies might be more similar between younger/older and autistic/non-autistic people than previously expected, although notable discrepancies between objective and subjective measures were present. They also substantiate previously reported parallel (i.e., similar) age-related effects between autistic and non-autistic people.

Lay Summary

In their way of remembering things, autistic people seem to show similarities to those of older age. We wanted to find out if these differences in memory strategies that autistic people use at younger age, might become an advantage as they get older. We studied 147 participants divided into four groups: younger and older adults with autism, and younger and older adults without autism. Participants completed a memory test where they had to remember patterns, a visual processing task where they had to judge the size of various objects, and a memory questionnaire where they judged their own memory and the use of memory strategies in daily life. Surprisingly, in the memory pattern test, using memory strategies helped all groups, although the older participants in both groups (autistic and non-autistic) were slower and less accurate. On both the memory task and visual

processing task no differences between autistic and non-autistic people were observed. However, autistic people rated their own memory as worse compared to non-autistic people and they reported using more memory strategies in daily life on the questionnaire. These results suggest that the ways people remember things might be more similar than previously expected, even between younger and older people and between those with and without autism. Our study contributes to understanding how memory works in autism and illustrates that memory tasks and memory questionnaires can show different results.

KEYWORDS
aging, autism, memory strategies, visual memory

INTRODUCTION

Autism is increasingly recognized throughout all phases of life. This awareness has sparked many new questions in autism research, particularly on adult outcomes. Differences in cognitive functioning are observed in autistic young people (e.g., differences in the perception of global vs. local stimuli, Frith, 2012) and autistic adults consistently rate their own cognitive functioning as worse than their non-autistic peers (for an overview see Groenman et al., 2022). Therefore, studies capturing how cognitive functioning evolves in older autistic people are essential ("the aging analogy", Bowler, 2007). Various patterns of cognitive aging in autism have been hypothesized (also see Geurts & Vissers, 2012), yet no consensus has been reached on whether autistic aging is most likely to be accelerated (faster), parallel (at equal pace) or even protective (slower) compared to non-autistic aging (Pagni et al., 2022; Torenvliet et al., 2023). The current study aims to investigate potential mechanisms of cognitive aging in autistic individuals, by studying hypothesized differences in cognitive strategies. Specifically, we aim to unravel potential differences in the use of semantic strategies during visual memory performance in autistic and older adults.

Considering the increased recognition of compensatory strategies in autistic adults in social situations and everyday life (Livingston et al., 2019; van der Putten et al., 2023), cognitive compensatory strategies may be likely in autism. The deliberate and repetitive use of compensatory strategies to navigate in the neurotypical world, although described as cognitively taxing (Livingston et al., 2019), might result in enhanced and/or altered use of cognitive strategies. For example, preparing notes of peoples interests to avoid social silences might also be an effective strategy in the memory domain. It has been previously suggested that autistic adults show compensatory strategies in declarative memory (Ullman & Pullman, 2015) and increased neuronal compensation in episodic memory (Hogeveen et al., 2020). Another study indicated that autistic people rate themselves better at monitoring their own thoughts (Grainger et al., 2014), hinting at more explicit cognitive strategy use. Hypothetically, such altered cognitive strategies lead to altered age-related effects in autism. If strategies used by non-autistic people are sensitive to age-related decline, whereas autistic strategies are not, this might result in reduced age-related decline in autism. However, cognitive strategies in older autistic adults received little attention. As differential visual processing seems a key feature of autistic cognitive functioning (Mottron et al., 2006), and protective age-related patterns have been observed on visual (working) memory tasks (Lever et al., 2015; Lever & Geurts, 2016a; but see Torenvliet et al., 2021; Tse et al., 2019), and in visual neuronal networks (Bathelt et al., 2020), visual memory seems a reasonable starting point for studying cognitive strategies in autistic adults in more detail.

In non-autistic people, visual memory is known to decline from the age of 65, or even at younger ages following a nearly linear pattern throughout middle- and late adulthood (Logie & Maylor, 2009; Salthouse, 2019). This decline seems at least partly mediated by the diminished availability of attentional resources leading to less enriched processing at both encoding and retrieval (see for an overview: Craik & Byrd, 1982). Arguably, this forces older adults to use less effective cognitive strategies. An efficient cognitive strategy in visual memory is to use semantic affordance of the visual input to facilitate chunking and use of long term memory (LTM) resources to enhance recollection (Hamilton, Brown, & Rossi-Arnaud, 2018). This was examined by the Visual Patterns Test (VPT; Brown et al., 2006; Della Sala et al., 1997), which explores the ability to use semantic cognitive strategies by comparing stimuli with either high or low semantic affordance: high semantic stimuli are more easily verbalized as they are more likely to resemble meaningful objects, like a letter or object, whereas low semantic stimuli are configured randomly and thus less easily verbalized (Brown et al., 2006). When comparing younger and older adults on a recall version of the VPT older non-autistic adults do not benefit from high semantic affordance, whereas younger adults do (Hamilton, Brown, & Rossi-Arnaud, 2018). Older adults may not have the time or attentional resources available to exploit semantic strategies. As such, largest age-related differences were observed on those stimuli (i.e., high semantic) that elicit a difference in strategy use at younger and

older age. However, it should be noted that another study investigating the recall VPT, did not observe strategic differences between younger and older adults. Memory recall was generally worse in older adults, yet both groups benefitted from semantic affordance (Nicholls & English, 2020). The researchers suggested that this may be due to differences in task timing as the second study allowed for more time between encoding and retrieval (10 s vs. 1 s in the original study). Potentially, this gave older adults the opportunity to use more effective strategies. In sum, age-related strategy differences in visual memory warrant further research, yet seem largest with short maintenance windows.

Like older non-autistic people, autistic adolescents might not exploit the same strategies to enhance visual memory performance as their non-autistic peers. On a recognition version of the VPT, autistic adolescents performed worse on high semantic trials compared to non-autistic adolescents, with no difference on low semantic trials (Mammarella et al., 2014). This indicates a reduced benefit of semantic affordance, without a global deficit on visual memory. Additionally, it been suggested that visual processing is more refined in autism (Mottron et al., 2006). A recent study reported that autistic traits in young adults were positively associated with better performance on low semantic trials, without an effect on high semantic trials (Nicholls & Stewart, 2022). This pattern was substantiated by research on the Just Noticeable Difference Size task (JND Size task), which aims to capture the preciseness of visual representations without the involvement of semantic memory strategies (Thompson et al., 2006). Autistic systemizing traits also related positively to performance on the JND Size task, indicating enhanced sensitivity to discriminate between two objects in those with high autistic traits (Hamilton, Mammarella, & Giofrè, 2018). These findings suggest a reduced use of semantic strategies, yet enhanced visual processing in autism. As previous research focused only on autistic adolescents, or was based on autistic traits, it remains unclear how these strategies develop with older age.

Given that autistic individuals may be less reliant on semantic affordance in visual memory, and semantic affordance may be a less available memory strategy at older age, autistic adults might show an advantage over non-autistic adults at older age by employing more *visual* than *verbal* memory strategies throughout life. The reliance on visual processing might hamper performance at younger age, but could result in relatively sustained performance at older age. To explore this, the current online study compared memory strategy use between autistic younger, autistic older, and non-autistic younger, and non-autistic older group on the VPT and JND Size task. Since previous research in autistic children used a recognition version of the VPT (Mammarella et al., 2014) and this format is more appropriate for online testing, we also used a recognition VPT. Additionally, we compared self-reported memory performance and strategy use on the Multifactorial Memory Questionnaire (MMQ; Troyer & Rich, 2002), and their self-reported strategy use after the two tasks between the four groups. We aimed to study differences in memory strategies in older and autistic adults, and gain additional understanding of how strategy differences at younger age, could influence performance at older age. It was hypothesized that younger and older autistic participants self-report worse memory performance, and more strategy use on the MMQ. Due to more effective use of visual strategies, we expected a so-called protective pattern on the VPT in which initial differences between autistic- and non-autistic young people are reduced, or even reversed at older age, especially on high semantic trials. On the JND Size task, equal or better performance was expected for the autistic as compared to the non-autistic groups with equal performance at young and older age.

METHODS

Participants

Power analysis using G*Power (Faul et al., 2007) indicated that we needed to recruit between 21 and 32 people per group ($n_{tot} = 128$) to be able to observe significant interactions between age and stimulus type, with a power of 0.80 and significance level (α) of 0.05 in our frequentist analyses. This was based on the effect size in previous literature ($f = 0.31$, Hamilton, Mammarella, and Giofrè (2018); Hamilton, Brown, and Rossi-Arnaud (2018), $n = 21$ per group) and adhering a more conservative standard medium effect size ($f = 0.25$, $n = 32$ per group).

In total, we recruited 147 participants of which 129 completed the VPT (see Table 1), via our previous study on cognitive aging in autism (Geurts et al., 2021), social media, and the personal network of the researchers. Inclusion criteria were that participants had to be either between 25 and 40 years (younger groups) or equal to/older than 65 years (older groups). In the autism groups, an additional inclusion criterium was that participants had to report having received a clinical diagnosis of autism, along with the year of diagnosis and the type of health professional (e.g., private certified professional or a major mental health institute) who provided the diagnosis. These diagnoses were not verified with diagnostic instruments (e.g., ADOS) since the study was conducted online. However, 60% of the autistic samples also participated in our previous studies on cognitive aging in autism, in which diagnoses were verified using the ADOS (−2) (Lever & Geurts, 2016b; Torenvliet et al., 2021). In the no autism group, two additional exclusion criteria were (1) a history of autism and (2) a first degree relative (child/parent/sibling) with an autism diagnosis. Participants were not excluded based on co-occurring conditions. Exclusion criterion was being unable to complete the online questionnaires or tasks.

TABLE 1 Demographic characteristics of the four groups in the VPT sample ($N = 129$).

	Young			Old		
	Autism ($N = 27$)	No autism ($N = 29$)		Autism ($N = 39$)	No autism ($N = 34$)	
Outcome	**Mean, SD (range)**	**Mean, SD (range)**	***t*-value**	**Mean, SD (range)**	**Mean, SD (range)**	***t*-value**
Age in years	36.99, 3.06 (28–40)	32.66, 4.59 (25–40)	**4.18****	71.72, 4.77 (65–82)	73.96, 5.12 (65–87)	−1.92
Age of diagnosis	24.97, 8.94 (4–36)	NA	NA	60.11, 7.34 (46–77)	NA	NA
AQ-10 total score[a]	6.74, 1.99 (1–9)	2.48, 1.82 (0–6)	**8.32****	7.26, 1.95 (2–10)	2.24, 1.63 (0–6)	**11.88****
Sleep quality (0–10)	5.07, 2.56 (0–8)	6.34, 1.88 (3–10)	**−2.11***	6.39, 2.30 (0–10)	7.24, 1.50 (3–10)	−1.86
Sleep quantity (hours)	7.15, 2.13 (1–10)	6.86, 0.99 (5–9)	0.64	6.89, 1.74 (2–10)	7.18, 1.00 (5–10)	−0.85
	N, % 1st	**N, % 1st**	**χ2-value**	**N, % 1st**	**N, % 1st**	**χ2-value**
Biological sex (M/W/O)	6/21/0 (22%)	10/19/0 (34%)	0.52	26/12/1 (67%)	20/14/0 (59%)	1.60
Education[b]	0/18/9 (0%)	1/13/15 (3%)	3.24	3/25/11 (8%)	2/16/16 (6%)	2.77
ADHD diagnosis (Yes/No)	3/24 (11%)	4/25 (14%)	<0.01	12/27 (31%)	0/34 (0%)	**10.38****
Psychiatric diagnosis[c], current (Yes/No)	5/22 (19%)	4/25 (14%)	0.01	5/34 (13%)	0/34 (0%)	2.89
Psychiatric diagnosis[d], past (Yes/No)	13/14 (48%)	3/26 (10%)	**8.03****	10/29 (26%)	3/31 (9%)	2.46
Neurological history[e] (Yes/No)	4/23 (15%)	0/29 (0%)	2.66	4/35 (10%)	2/32 (6%)	0.46
Drugs[f], 24-hours (Yes/No)	0/27	0/27	NA	0/27	1/27	NA
Alcohol[g], 24-hours (Yes/No)	1/26 (4%)	7/22 (24%)	3.25	12/27 (31%)	11/23 (32%)	<0.01

Note: M, men; W, Women; O, other; SD, standard deviation. Significant differences ($p < 0.05$) are in **bold**.
*$p < 0.05$; **$p < 0.01$.
[a]Autism Quotient (AQ) measured self-reported autism traits.
[b]Level of education was determined by the Verhage Coding System (Verhage, 1964), between slashes: junior secondary or practical education/senior secondary education or vocational college / university degree. The five lowest groups were concatenated.
[c]Anxiety disorder, $N = 6$; mood disorder, $N = 7$; schizophrenia, $N = 1$; personality disorder, $N = 2$; alcohol/drug dependency, $N = 1$; other, $N = 4$.
[d]Anxiety disorder, $N = 9$; mood disorder, $N = 21$; schizophrenia, $N = 1$; personality disorder, $N = 9$; alcohol/drug dependency, $N = 2$; other, $N = 4$.
[e]Stroke, $N = 3$; transient ischemic attacks, $N = 1$; epilepsy, $N = 1$; other, $N = 5$.
[f]One person reported cannabis use on the day before. Statistics could not be estimated due to empty cells. No one reported drug use on the day of the session.
[g]Five people reported having more than three units of alcohol on the night before (4–6). No one reported alcohol on the day of the session.

Materials

Questionnaires

A *General Questionnaire* (GQ) was administered to obtain information on participants demographic characteristics, neurodiversity (clinically established autism/ADHD diagnoses), psychiatric (e.g., anxiety disorder, mood disorder, schizophrenia)–and neurological history (e.g., stroke, epilepsy, brain tumor), and factors that could possibly influence performance, such as their self-rated sleep quality and quantity of the past night, and alcohol/drug intake in the 24-h prior to the experiment.

The *Autism-spectrum Quotient-10* (AQ-10; Allison et al., 2012) was administered to measure autistic traits. An example item is: *"I find it difficult to work out people's intentions*". A sum score ranging from 0 (low) to 10 (high) indicates whether participants report autistic traits. As findings on the psychometric properties of the AQ-10 have been mixed, the AQ-10 sum score is only used as a descriptive measure (Allison et al., 2012; Bertrams, 2021; Lundin et al., 2019).

The Dutch version of the *Multifactorial Memory Questionnaire* (MMQ; Troyer & Rich, 2002; van der Werf & Vos, 2011) was used to assess self-reported memory functioning. The questionnaire consists of three subscales: contentment, ability, and strategies which contain 18, 20, and 19 questions, respectively. Example items are: "*I am worried about my memory*" (contentment), "*How often do you forget something*" (ability), "*How often do you write down what you want to remember*" (strategies). Items are answered on a five-point subscale ranging from "totally disagree" (0) to "totally agree" (4) for the contentment subscale, "never" (0) to "always" (4) for the ability, and strategies subscales. After rescaling reversed items, total scores range from 0 to 72 for contentment, with zero indicating being very worried about their own memory functioning, 0–80 for ability, with zero indicating high forgetfulness, and 0–76 with zero indicating no strategy use. Thus, high scores can be interpreted negatively on the first two scales and positively on the last scale. The MMQ showed good to excellent internal consistency in both the autism (Cronbach's $\alpha = 0.86$–94) and no-autism groups (Cronbach's $\alpha = 0.81$–0.90). In other samples, it had good test–retest reliability ($r = 0.86$–0.93) (Troyer & Rich, 2002) and congruent validity to other memory scales ($r = 0.61$ to -0.89), yet discriminant validity to measures of general psychological distress (Symptom Checklist-90)

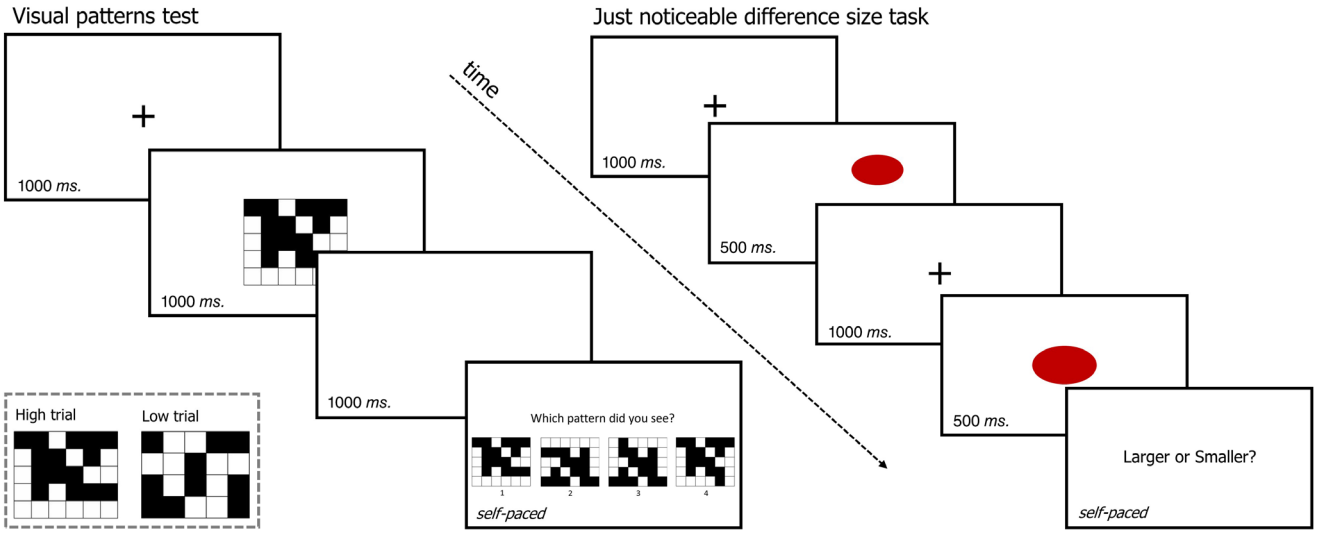

FIGURE 1 Example trial of the Visual Patterns Test (left) and Just noticeable difference size task (right). This VPT stimulus is classified as high semantic (e.g., "dinosaur"), whereas a low semantic stimulus would be randomly configured, see the gray dotted box for an example. In this example, we depicted one of the most elaborate high semantic stimuli, yet the total set consisted of stimuli with both elaborate, and more basic verbal labels (e.g., letters, numbers, symbols; Nicholls & English et al., 2020). The figure is for illustrative purpose and not plotted to scale.

is ambiguous, especially on the ability scale ($r = -0.60$, contentment: $r = -0.48$, strategy: $r = 0.28$; van der Werf & Vos, 2011).

Visual patterns test

Visual matrix patterns similar to the VPT stimuli used by Mammarella et al., (2014, adapted from Brown et al., 2006; Della Sala et al., 1997) assessed visual memory performance on a subset of high, and low semantic stimuli which were randomly sampled from the initial set of nearly 900 stimuli (Orme, 2009). Stimulus type (low versus high semantic) indicated the level of meaning that could be attributed to the stimulus (Orme, 2009). See Figure 1 for a schematic display of the task. On each trial, participants saw a black fixation dot at the center of a white screen. Subsequently, participants were presented a matrix of equal numbered black-and-white cells for a duration of 1 s and instructed to memorize the pattern. The matrix was replaced by a white screen for 1 s, and followed by four different matrices (numbered 1–4). One matrix was similar to the matrix shown before (i.e., the correct pattern), one matrix was the correct pattern rotated 180°, one matrix was the correct pattern with one random black/white cell replaced, and the last matrix was the one-cell replaced matrix rotated 180°. The order of four matrices was randomly determined on each trial. Participants were instructed to recognize the correct pattern and to respond by pressing the corresponding key (1–4) at their own pace. The subsequent trial was initiated after participants responded.

The task consisted of different levels, with levels referring to the number of black (and white) cells; thus Level 2 had two black cells and two white cells, Level 5 had five black cells and five white cells. Each level contained four trials, two high and two low semantic, which were presented in a random order. Participants practiced levels 2 and 3 to get familiar with the stimuli and the task. The experiment started at level 5 and progressed to level 15 in steps of 1, leading to 11 levels and 44 experimental trials in total. All participants completed all trials, regardless of their performance. Feedback was provided during practice trials only.

Trials were indicated as outliers if reaction times (RTs) were slower or faster than three standard deviations (SDs) below the individuals mean, or faster than 1000 ms. Outcome measures were accuracy and mean correct RT. Accuracy was calculated as the percentage of correct trials after outlier removal. Mean correct RT was calculated based on correct trials after outlier removal. Previous versions of the VPT have shown to have good test–retest reliability ($r = 0.73$–0.75) and excellent parallel forms concordance ($r = 0.88$) (Della Sala et al., 1999). Split-half reliability of the current version is poor for accuracy (high: $r = 0.31$, low: $r = 0.40$), yet good for mean correct RT (high: $r = 0.83$, low: $r = 0.84$).[1]

Just noticeable difference size task

An adapted version of the *JND Size* task (adapted from Hamilton, Mammarella, and Giofrè (2018); Hamilton, Brown, and Rossi-Arnaud (2018); Thompson et al., 2006) assessed the precision of visual memory. Figure 1 illustrates an example trial. A trial started with the presentation of a black fixation cross at the center of

[1]To calculate split-half reliability, we randomly divided the trials of each type and per level, assigning one trial to one half and the other trial to the other half. In this way, we ensured that each half contained a trial from each level. Subsequently, the split-half reliability between these halves was determined by following the Spearman-Brown prophecy for each trial type (high vs. low) separately.

a white screen for 1000 ms. Subsequently, a red ellipse or blue square was shown for 1000 ms, and participants were instructed to remember the size of the stimulus. To reduce the effects of iconic memory (e.g., afterimages), the memory stimulus had three fixed sizes and was randomly displayed on one of the four fixed locations on the screen (left upper to right lower). The stimulus was replaced by a black fixation cross on a white screen for another second. Subsequently, a probe with the same shape was presented at the center of the screen. Participants indicated whether the probe was smaller or larger than the memory stimulus by pressing the K-key or G-key, respectively. The next trial was initiated after participants responded.

Participants practiced four trials to get familiar with the task. Subsequently, a staircase procedure was applied to estimate the JND for discriminating the probe stimulus from the memory stimulus. Size differences between the memorized and probe stimulus decreased progressively, by varying the size of the probe. Based on individual performance, participants started with 50% size difference, with the probe being 50% smaller or larger than the memory stimulus. Participants progressed to smaller size differences after two subsequent correct responses and regressed to a larger size difference after each incorrect response. Step sizes started at 10%, narrowed to 5%, and finally to 2.5% after a set of five reversals. Reversals were defined as switching between correct and incorrect responses, as an indication of nearing chance level performance.

Outlier trials were defined as in the VPT. Outcome measures were JND score, accuracy and mean correct RT. JND score was defined as the average size difference in the final set (2.5%) of reversals. Accuracy and mean correct RT were computed as in the VPT, using the final set of reversals. The JND is known to have reasonable internal consistency (Cronbach's $\alpha = 0.68$) (Hamilton, Mammarella, & Giofrè, 2018).

Subjectively reported performance and strategy use on the VPT and JND task

Directly after completion of the VPT and JND Size task, participants rated their effort, performance, and concentration on each task. Ratings were given on a scale from 1 (minimum) to 10 (maximum). Additionally, we asked whether or not they used a particular strategy on either task (yes/no/I don't know). For those who indicated to use a particular strategy, we asked an open-ended question to describe this strategy.

Procedure

The study was conducted fully online, using Qualtrics (questionnaires) and NeuroTask (cognitive tasks; Murre, 2016). After providing informed consent, participants completed the general questionnaire, AQ-10 and MMQ. Before transferring to NeuroTask, participants created a personal ID to ensure that the data between Qualtrics and NeuroTask could be linked appropriately. In NeuroTask, participants completed the VPT and JND Size task in that order. Participation took 45–60 min, and participants received €7.50 for their participation. The study was approved by the ethical review board of the Department of Psychology of the University of Amsterdam (2022-BC-14316).

ANALYSES

Frequentist analyses were conducted in R (Version 3.6.1; RStudio Team, 2020), reproducible code is provided as an R-Markdown (see S7). After analyzing group differences on general sample characteristics, we followed our pre-registered analysis plan (https://aspredicted.org/SHX_W6S). First, we analyzed the effects of age, and autism on self-reported memory ability, contentment, and strategy use by conducting three two-way factorial ANOVA with age and autism as between subjects' factors and the MMQ subscales as outcome variables. Second, we analyzed the effects of trial type (low/high semantic), age, and autism on VPT performance by conducting two three-way mixed ANOVA ($2 \times 2 \times 2$), with age and autism as between subjects' factors, trial type as within subjects' factor, and accuracy and mean correct RT as outcome variables. Two two-way mixed ANOVAs (age*trial type, autism*trial type) and one two-way factorial ANOVA (age $\times$ autism) were conducted to test the consecutive two-way interactions. In case of significant interactions, planned contrasts (paired t-tests) assessed differences between high and low trial in each group. Bonferroni-Holm corrections were used to correct for multiple comparisons ($k = 4$). Third, we analyzed the effects of age and autism on JND performance by conducting three two-way factorial ANOVA with age and autism as between subjects' factors, and JND score, accuracy, and mean correct RT in the final set of reversals as outcome variables. To be able to interpret potential null-findings (i.e., the absence of statistical differences), all analyses (MMQ, VPT, JND) were repeated using Bayesian model comparisons in JASP using a default prior ($r = 0.5$; JASP Team, 2022). Bayes Factors (BF_{01}) larger than >3 indicated substantial evidence in favor of the null hypothesis (the best model), whereas BFs <0.3 indicate substantial evidence in favor of the alternative hypothesis/model (other models; Jarosz & Wiley, 2014).

RESULTS

One-hundred-and-fifty-one participants completed the MMQ (20% newly recruited; see Geurts 2021),

TABLE 2 Descriptive statistics of the MMQ subscales split by age and autism groups.

		Autism	No autism
	Outcome	Mean, SD (range)	Mean, SD (range)
Young	Contentment	48.19, 13.16 (23–69)	55.65, 9.31 (34–71)
	Ability	55.22, 12.67 (30–78)	64.1, 8.14 (37–74)
	Strategy use	27.47, 12.37 (6–66)	24.58, 9.66 (7–45)
Old	Contentment	44.04, 15.02 (9–72)	52.73, 9.54 (32–72)
	Ability	56.3, 13,00 (12–73)	63.49, 7.57 (43–76)
	Strategy use	24.04, 10.39 (6–47)	19.41, 7.14 (7–34)

Note: No planned contrasts were performed as interactions between group (autism/no autism) and age (young/old) were nonsignificant.

138 completed the VPT, and 131 completed the JND. Four participants in the younger no autism group were excluded for reporting a close family member with autism. Five participants ($n_{autism} = 3$ [2 older, 1 younger], $n_{no\text{-}autism} = 2$ [1 older, 1 younger]) were excluded from the VPT as their response pattern indicated taking multiple breaks during the task and responses were exceptionally slow compared to the group mean performance (mean RT >3 SD) even after removing individual outlier trials. There were no participants excluded for the JND size task.

Demographic characteristics

Demographic characteristics of the VPT sample ($N = 129$) are provided in Table 1 and were statistically similar in the (total) MMQ sample, see Table S1. The autism group was significantly older than the no autism group in the younger participant groups, yet age was not significantly different between the older groups, nor between the total autism and no autism groups (main effect autism: $F(1,128) = 0.59$, $p = 0.44$, $\eta^2 < 0.01$). Autistic traits were higher in both autistic groups (main effect autism: $F(1,128) = 204.52$, $p < 0.01$), but did not significantly differ between older and younger participants (main effect age: $F(1,128) = 1.14$, $p = 0.29$, $\eta^2 = <0.01$). Since three of our non-autistic participants (1 older, 2 younger) scored above the cut-off of 5 on the AQ-10—indicating potential autism (Booth et al., 2013), we performed sensitivity analyses to examine whether these participants had a pronounced impact on the pattern of our results. These analyses showed no differences with the original results.

Younger, and autistic participants rated their sleep quality significantly worse than older, and non-autistic participants (main effect age: $F(1,146) = 8.16$, $p < 0.01$, $\eta^2 = 0.06$; main effect autism: $F(1,128) = 7.79$, $p = 0.01$, $\eta^2 = 0.06$), yet no differences were observed on sleep quantity (p's > 0.90). The older groups reported sex assigned at birth as male significantly more often than the young groups (main effect age: $\chi^2(1) = 16.55$, $p < 0.01$), yet no differences between the autism and no autism groups were present. Autistic participants reported higher rates of ADHD (main effect autism: $\chi^2(1) = 5.26$, $p = 0.02$), and past psychiatric disorders (main effect autism: $\chi^2(1) = 13.12$, $p < 0.01$) compared to non-autistic participants.

TABLE 3 VPT descriptive statistics per group, per trial type.

			Autism	No autism
	Outcome	Type	Mean (SD)	Mean (SD)
Young	Accuracy	High	0.78 (0.10)	0.77 (0.09)
		Low	0.72 (0.13)	0.76 (0.12)
	Mean correct RT[a]	High	2939 (821)	2888 (693)
		Low	3286 (1046)	3243 (880)
Old	Accuracy	High	0.74 (0.12)	0.73 (0.10)
		Low	0.69 (0.11)	0.68 (0.09)
	Mean correct RT[a]	High	3327 (869)	3051 (781)
		Low	3641 (935)	3482 (1196)

Note: RT, reaction time; No planned contrasts were performed as none of the interactions between type (high/low), group (autism/no autism) or age (young/old) were significant.
[a]In milliseconds.

Self-reported memory contentment, ability, and strategy use on the MMQ

Descriptive statistics of the MMQ subscales are provided in Table 2. A significant main effect of autism was observed on contentment ($F(1,146) = 16.00$, $p < 0.01$, $\eta^2 = 0.10$), ability ($F(1,146) = 19.40$, $p < 0.01$, $\eta^2 = 0.12$), and strategy use ($F(1,146) = 5.49$, $p = 0.02$, $\eta^2 = 0.04$) with autistic participants reporting less contentment and ability, yet more strategy use. A significant main effect of age was observed on strategy use ($F(1,128) = 5.93$ $p = 0.02$, $\eta^2 = 0.04$), but not on the other subscales (p's > 0.06). Younger participants reported more strategy use than older participants. Interactions between age and autism were all non-significant (p's > 0.60). Therefore, no planned contrasts were performed. Bayesian model comparisons yielded similar results, with moderate to strong evidence *against* models containing an Age*Autism interaction ($BF_{01} = 3$–21), see Table S2.

Strategy use and memory performance on the VPT

Descriptive statistics of the VPT task are provided in Table 3[2] and Figure 2. For both outcome measures, a

[2]Of note, we conducted additional analyses with outcomes that are commonly used on the recall VPT, namely: maximum span and mean span (as in Brown Nicholls & Stewart, 2022). A cut-off criterion in which both trials on a level were incorrect was chosen. This yielded similar results as overall task accuracy. Results are included in S7.

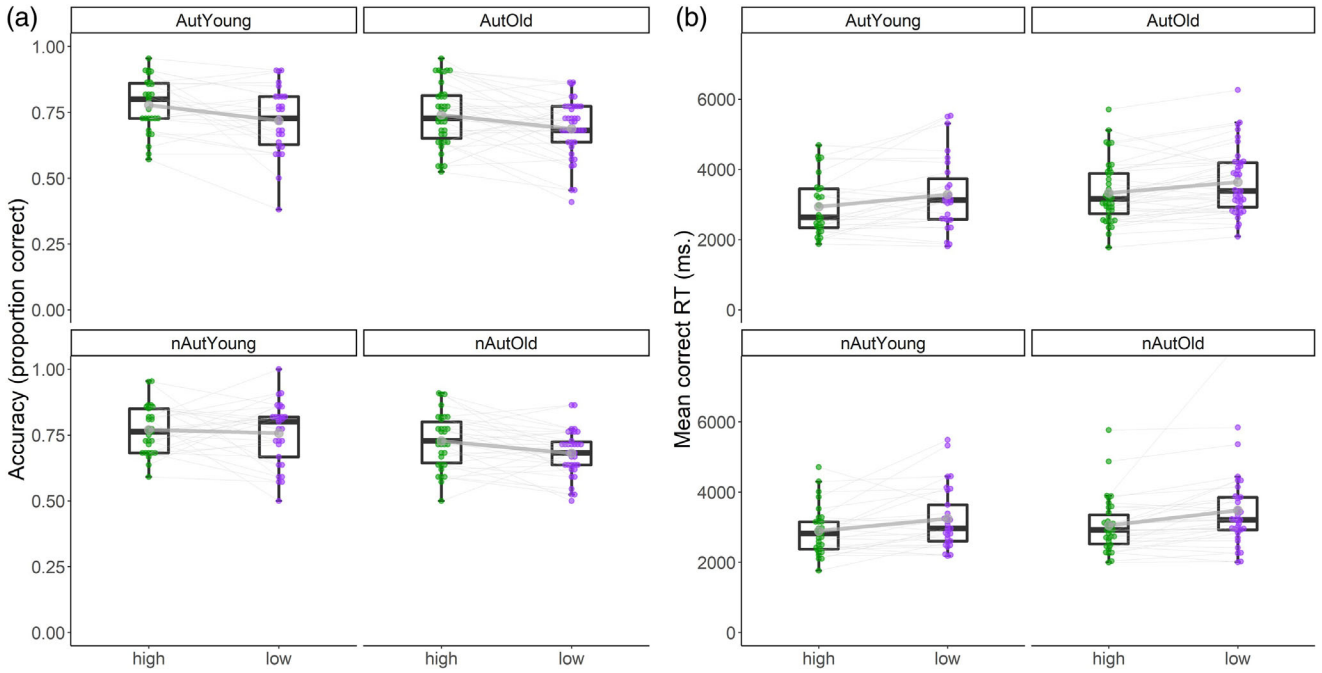

FIGURE 2 Results for the visual pattern tests. (a) Accuracy (proportion correct) as a function of trial type (low versus high semantic) for each of the four groups (Autism × Age). (b) Mean correct reaction time as a function of trial type (low versus high semantic) for each of the four groups (Autism × Age). Boxplots display median, IQR, and 95% confidence intervals, gray dots (with lines) display group means. n.s., non-significant; *, Holm-corrected $p < 0.05$; **, Holm-corrected $p < 0.01$.

significant main effect of trial type was observed (accuracy: $F(1,128) = 16.04$, $p < 0.01$, $\eta^2 = 0.04$; mean correct RT: $F(1,128) = 38.65$, $p < 0.01$, $\eta^2 = 0.04$), with participants performing more accurate and faster on high semantic stimuli than on low semantic stimuli. For both outcome measures, a main effect of age was observed (accuracy: $F(1,256) = 11.83$, $p < 0.01$, $\eta^2 = 0.04$; mean correct RT: $F(1,256) = 6.73$, $p = 0.01$, $\eta^2 = 0.02$), with older participants scoring less accurate and slower than younger participants. Main effects of autism did not reach significance (p's > 0.18), indicating no significant difference between autistic and non-autistic participants on VPT performance. All other effects failed to reach significance (p's > 0.26). Since none of the interactions were significant, planned contrasts were not performed. Bayesian model comparisons are shown in Table S3, and confirmed these results, showing evidence for models containing main effects of type and age, and substantial evidence *against* models containing interactions ($BF_{01} > 4.35$). For RT (not accuracy), it should be noted that although the best model contained main effects of age and type, this model performed only slightly better (anecdotal evidence) than a model without age (BF age + type vs. type = 1.37) or a model with autism added (BF age + type vs. age + type+autism = 1.99). These findings indicate that older participants show less effective visual memory abilities, but a similar benefit of using semantic strategies compared to younger participants.

Next to these pre-registered analyses, we performed post-hoc analyses to gain insight into the experienced performance on the VPT task. Three two-way (2 × 2) factorial ANOVAs indicated no significant differences in self-reported effort, performance, and concentration on the VPT task between the four groups (p's > 0.13). A summary of these results is provided in Figure S1. Younger adults reported more strategy use on the VPT (autism: 70%, no autism: 70%) than older adults (autism: 58%, no autism: 42%), although not statistically significant ($\chi^2_{age} = 4.99$, $p = 0.08$). We conducted a qualitative assessment (details in S4) of the self-reported strategies on the VPT by clustering the described strategies into categories. This suggested that most participants used a verbal strategy, such as naming, counting, or "creating a pattern". Visual strategies, such as visualization

TABLE 4 JND descriptive statistics per group.

		Autism	No autism
	Outcome	**Mean, SD**	**Mean, SD**
Young	Score	1.06, 0.04	1.06, 0.03
	Accuracy	0.72, 0.13	0.73, 0.13
	Mean correct RT[a]	900, 827	790, 323
Old	Score	1.05, 0.03	1.06, 0.04
	Accuracy	0.70, 0.12	0.72, 0.13
	Mean correct RT[a]	966, 498	846, 493

Note: No planned contrasts were performed as none of the interactions between group (autism/no autism) and age (young/old) were significant.
Abbreviation: RT, reaction time.
[a]In milliseconds.

(imprinting) and segmenting (focussing on a part of the stimulus) were also mentioned. Some participants reported a mixture of both verbal and visual strategies.

Strategy use and memory performance on the JND size task

Descriptive statistics of the JND Size task are in Table 4. As JND scores were not normally distributed (negatively skewed), we used bootstrapped p values for this outcome variable. We observed no significant main effects of age or autism, nor significant interactions between age and autism (all p's > 0.24) on any of the dependent variables, see Figure S2. Estimated effect sizes were extremely small ($\eta^2 < 0.01$), except for a non-significant main effect of autism on mean correct RT ($\eta^2 = 0.01$). No planned contrasts were performed since none of the interactions between age and group were significant. Bayesian model comparisons are provided in Table S4, and substantiated the frequentist findings showing moderate evidence for the null models as compared to all other models ($BF_{01} = 5–9$). Based on these results neither age nor autism seems predictive of JND Size task performance.

Post-hoc analyses on self-rated effort, performance, and concentration did not show significant effects of age, autism, or their interaction (p's > 0.16). Only 16 participants (13%) indicated to use a strategy on the JND, equally spread across the four groups. Participant's descriptions indicated that everyone used visual strategies.

DISCUSSION

The current study investigated memory performance and strategy use in autistic and older adults. Our primary interest was to investigate whether limited use of semantic memory strategies and enhanced visual memory in younger autistic people would lead to advantageous visual memory performance at older age, resulting in reduced susceptibility to age-related cognitive differences. In this way, our study aimed to elaborate on cognitive strategy use in autistic and older adults. Unexpectedly, the current results indicated that objective memory strategy use was largely similar between autistic and non-autistic adults, and between younger and older adults. Bayesian model comparisons indicated anecdotal to substantial evidence *against* differential strategy use in both autistic and older adults.

Equal memory performance, and strategy use in autism

Contrary to our hypothesis, autistic people, younger and older alike, benefitted from semantic affordance on the VPT resulting in similar accuracy, and reaction time on high semantic stimuli compared to non-autistic people. Autistic people did not show enhanced visual processing, as autistic- and non-autistic performance differences on low-semantic stimuli and the JND Size task were non-significant. This is in contrast to studies showing an enhanced visual memory in those with high autistic traits (Hamilton, Mammarella, & Giofrè, 2018; Nicholls & Stewart, 2022), and diminished use of semantic affordance in autistic adolescents (Mammarella et al., 2014). As our study extended previous findings to those with autism instead of autistic traits, and to autistic adults instead of adolescents, these between-study differences may be explained by differences in sample characteristics. Age-related differences in autistic and non-autistic people were similar, with significantly slower and less accurate responses in older, compared to younger individuals. This is consistent with our previous observations of parallel cross-sectional and longitudinal age-related effects during autistic adulthood (Torenvliet et al., 2023). Based on these results, visual memory performance and objective strategy use seems similar in autistic- and non-autistic adults, with parallel age-related patterns.

Despite these non-significant differences in objective memory performance, subjective memory was rated significantly different across groups. Lower self-reported memory ability and contentment, and higher rates of strategy use, were reported by autistic compared to non-autistic adults. This highlights the often reported discrepancy between objective and subjective memory performance in autism (Groenman et al., 2022). One might argue that a structured, single-focused environment does not reflect the same demands that autistic people experience daily. However, given the limited distinction between memory complaints on the MMQ and measures of psychological distress (van der Werf & Vos, 2011), in addition to increased rates of psychological distress in autistic adults (e.g., Lever & Geurts, 2016b), we also need to consider the possibility that autistic adults have an increased sensitivity to the experience of cognitive difficulties (see also Stewart et al., 2018). As a large number of autistic people approach late adulthood today (Russell et al., 2022) and subjective cognitive functioning may serve as an indication of neurodegenerative disease (Jessen et al., 2020), these results highlights the necessity of exploring the predictive power of both subjective and objective cognitive challenges in autism.

Reduced memory performance, yet equal strategy use at older age

The current study also investigated differences in semantic/visual strategy use as measured with the VPT between younger and older adults. Both in our autistic and non-autistic groups, age affected performance, with slower and less accurate responses in the older compared to the

younger groups. Unexpectedly, both autistic and non-autistic older adults benefited from semantic affordance. Whereas an age-related decline in visual memory is in line with previous literature (Logie & Maylor, 2009; Salthouse, 2019), it is surprising that the use of semantic affordance was unaffected by age, as previous research indicated a remarkable reduction in the ability to benefit from semantics with a similar paradigm (Hamilton, Brown, & Rossi-Arnaud, 2018), although not consistently (Nicholls & English, 2020). Possibly, older adults develop greater expertise in using semantic strategies, which may help compensate for their overall greater difficulties with the task. This idea is supported by the observed faster reaction times on high semantic trials compared to low semantic trials. As noted by others (Nicholls & English, 2020), these faster reaction times may also indicate that semantics can be activated rather automatically, instead of being sought out strategically.

Inconsistent findings: Recognition versus recall

The discrepancies in age-related effects in strategy use between the current study and a previous study (Hamilton, Brown, & Rossi-Arnaud, 2018), might arise from differences in task administration. In the current study we used a VPT recognition task, whereas Hamilton and colleagues used a VPT recall task. It is likely that due to a reduction in attentional demands, the recognition version of the VPT allows older participants to use semantic affordance more easily. This is consistent with previous research suggesting that additional time enhanced the use of semantic affordance on the recall VPT in older adults (Nicholls & English, 2020). Our results provide additional evidence for the idea that, under the right circumstances, older adults are able to recruit semantic strategies effectively. Nonetheless, a direct comparison between a recall and recognition version of the VPT seems a useful next step in determining age-related differences in semantic strategy use during visual memory retrieval.

Similarly, the lack of strategic differences between autistic and non-autistic participants could have been due to the usage of a recognition VPT. It has been previously suggested that autistic people are generally better at recognition than recall (Desaunay et al., 2020). Additionally, in the verbal domain, differences in strategy use seem mainly present in free recall and not in recognition (Bowler et al., 2008). However, the absence of differences between the autistic and non-autistic group was unexpected as the Mammarella et al. (2014) study on autistic adolescents also used a VPT recognition paradigm (similar to ours) and did find reduced semantic strategy use in autistic adolescents. Therefore, an alternative hypothesis is that autistic people develop semantic strategies at a slightly older age, and "catch-up" with their peers around young adulthood. Again, future research comparing autistic adults on a recall and recognition version of the VPT can provide further insights into differences in strategy use between autistic and non-autistic adults.

Strengths & limitations

The current study had several strengths, such as the clear theoretical framework, its pre-registered design and analyses, and the use of Bayesian statistics to confirm the absence of interaction effects. However, it must also be viewed in the light of certain limitations. First, this study dealt with the merits and pitfalls of online studies. On the one hand, administration is standardized; resulting in more exact timing of the tasks compared to non-computerized versions of the VPT, and the exclusion of test leader effects. On the other hand, there is less environmental control than in offline settings, possibly leading to more variance within the data (Feenstra et al., 2017; Norman et al., 2010). Especially given the role of attentional demands, a direct comparison between online and offline administration might be useful to establish the validity of these tasks in an online setting. Nevertheless, we were able to replicate previous findings such as an effect of trial type in the VPT (Hamilton, Brown, & Rossi-Arnaud, 2018; Nicholls, 2020), indicating that the experimental setup worked properly. Moreover, experimental differences between online and lab-based testing are usually small (for an overview, see Pronk et al., 2022), and self-reported effort, concentration, and motivation did not indicate systematic group differences in the current study. A thorough inspection of reaction times allowed us to exclude those participants who were likely not adhering the study protocol. However, it should be kept in mind that the current task had poor split-half reliability for accuracy. The inclusion of additional trials might increase the reliability of the task in the current set-up in future studies.

Online testing expanded our sample *geographically*, to those participants not willing or able to travel to test locations, and *demographically*, to those people who may struggle to participate in person due to physical or mental health problems. However, the generalizability of our results was limited to those who could participate independently and with internet access. Particularly regarding our age-related results, this could have caused the current conclusions to be too optimistic. Indeed, compared to the Hamilton, Mammarella, and Giofrè (2018); Hamilton, Brown, and Rossi-Arnaud (2018) study our older groups were relatively young (mean age: 72 years vs. 81 years). Nonetheless, it is uncertain whether in an offline setting the older autism group could have been much older, as it is hard to recruit older autistic participants (Torenvliet et al., 2023). Furthermore, our study primarily included autistic adults diagnosed in adulthood. While this limitation might raise concerns about the generalizability of our results, it underscores the pervasive issue of

underdiagnosis among autistic (older) individuals, as noted by O'Nions et al. (2022). By including (older) autistic adults, our research highlights the necessity of studying and supporting autistic adults throughout their lifespan. Finally, we could not confirm diagnoses in all autistic participants by instruments like the ADOS, which could have led to the inclusion of people with invalid diagnoses. However, all participants indicated being diagnosed by a major mental health institute or certified mental health professional.

Next to the effects of online testing, we need to consider the effects of co-occurring conditions in autism. Our autistic younger group showed lower self-reported sleep quality and a more extensive psychiatric history compared to the non-autistic younger group. In the autistic older group, co-occurring ADHD was frequently reported, especially compared to the non-autistic older group. Although large differences in co-occurring conditions between autistic and non-autistic people are not unique to this study (Lever & Geurts, 2016b), it remains unsure whether we capture the unique effects of autism or that these effects coincide with other conditions. Especially when considering the observed differences in self-reported memory difficulties, our effects could be inflated due to the effects of co-occurring conditions. However, since the vast majority of autistic people deal with psychiatric co-occurring conditions, including autistic adults with psychiatric comorbidities is essential for a more comprehensive understanding of autism. Still, in future studies, it is vital to include large samples in which the effects of co-occurring conditions can be modeled separately, to assess the exact impact of both autism and its co-occurring conditions on memory strategies.

Finally, the younger autistic and non-autistic groups differed significantly in age, with the young autistic group being slightly older (~4 years) than the young no-autism group. Although we consider this difference minimal in comparison to the age differences under investigation in this study (i.e., young groups: 25–40 years, older groups: 65+ years) and in a fairly non-pivotal time in development, future studies could focus on exactly matching the age of the participants across all groups.

CONCLUSIONS

Taken together, the current study provides evidence for successful use of semantic strategies in autistic and older adults, in those with (above) average intellectual disabilities. At least in a recognition format, autism and older age result in less differences in cognitive strategy use than previously expected. Consistent with our earlier work (Torenvliet et al., 2023), we demonstrated parallel age-related effects between those with- and without autism, reducing the likelihood of both accelerated and protective age-related patterns, at least in adulthood.

ACKNOWLEDGMENTS

The authors would like to thank Robert Jertberg for his help with programming the online study protocol. We would also like to thank all our participants for the effort and time they have put into this study. Finally, we would like to thank our think tank of autistic/older adults for their instrumental contributions to this work.

FUNDING INFORMATION

This study was funded by the VICI Grant (453–16-006) awarded to HMG by the Netherlands Organization for Scientific Research (NWO).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Torenvliet, C., Groenman, A. P., Van der Burg, E., Charlton, R. C., Hamilton, C. J., & Geurts, H. M. (2024). Memory strategies in autistic and older adults. *Autism Research*, *17*(10), 2092–2104. https://doi.org/10.1002/aur.3195