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Citation: Ring, M., Gaigg, S. B. & Bowler, D. M. (2016). Relational Memory Processes in Adults with Autism Spectrum Disorder. Autism Research, 9(1), pp. 97-106. doi: 10.1002/aur.1493

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Relational memory processes across the adult lifespan in individuals with Autism Spectrum Disorder

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The first author was supported by a Doctoral Research Studentship from City University London. The results reported in this manuscript were presented at the International Meeting for Autism Research (May, 2014) in Atlanta, Georgia, USA.

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Abstract

Research into memory in Autism Spectrum Disorder (ASD) suggests intact item memory but difficulties in forming relations between items (Bowler, Gaigg & Lind, 2011). This pattern closely resembles that seen in typically developed (TD) older adults thus supporting the 'ageing analogy' (Bowler, 2007). In this study we tested memory for items as well as for sequential, spatial and associative relations between items with the same paradigm using abstract shapes in ASD and TD individuals. Participants studied shape triplets on a computer-screen and memory was subsequently tested either for the individual items making up the triplets, the screen-locations, the order or the combinations of items presented at study. We also examined age-related differences in memory across the mid-adult lifespan in both groups. Performance was significantly lower in the ASD group on all 4 tasks but particularly on the relational tasks. When considering order memory and age-related differences across the lifespan (20-62 years), we found a significant decrease in order memory with increasing age for the TD but not the ASD group. Younger ASD individuals performed significantly worse on the order task compared to younger TD but not older TD individuals. Whereas older ASD and older TD individuals performed similarly, suggesting a parallel between the memory performance of ASD individuals and that of older TD adults. Results are in line with evidence of relational memory difficulties in people with ASD (Bowler et al., 2011) and broadly support the 'ageing analogy' (Bowler, 2007) of autistic memory.

Keywords: ageing analogy, item memory, relational memory, Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is characterised by difficulties in social interaction, social communication and by the presence of restricted and repetitive behaviours (American Psychiatric Association, 2013). In addition it is associated with a complex cognitive profile which includes a particular pattern of strengths and weaknesses in the domain of memory (Boucher & Bowler, 2008; Boucher, Mayes & Bigham, 2012). Previous research suggests intact performance on tasks that probe memory for individual items of information such as individual words or pictures of objects that make up a study list (Bowler, Gardiner & Grice, 2000; Hauck, Fein, Maltby, Waterhouse & Feinstein, 1998). In addition, performance is typically also preserved on supported test procedures such as recognition tests where participants only need to identify rather than generate the studied items (task support hypothesis- Bowler, Gardiner & Berthollier, 2004). By contrast, difficulties are often observed on tasks that probe memory for associations between items (Bowler, Gaigg & Gardiner, 2008; Gaigg, Gardiner & Bowler, 2008) or between items and their context. Examples of the latter are difficulties in remembering the locations for or colours of objects (Bowler, Gaigg & Gardiner, 2014; Ring, Gaigg & Bowler, under review; Semino, Gaigg, Bowler & Ring, 2013), remembering the temporal order of items (Poirier, Martin, Gaigg & Bowler, 2011; Gaigg, Bowler & Gardiner, 2014), or recalling in what modality words were presented or by whom (Bowler et al., 2004). Memory difficulties tend to be particularly pronounced in ASD when test procedures provide little support, such as in the case of free-recall test procedures (e.g., Bowler et al., 2008).

The patterning of memory in ASD is similar to that observed in typically developed older adults (TD OA) who also show decreased performance on unsupported free recall tasks but better performance when more support is provided at test such as in recognition test procedures (Craik & Anderson, 1999). In addition, paralleling demonstrations of relational memory difficulties in ASD (Bowler et al., 2011), an associative deficit hypothesis for TD

OA suggests that older age is associated with particular difficulties in forming associations between units of experience in memory (Naveh-Benjamin, 2000). These similarities between the memory profile in ASD and TD OA were formally noted by Bowler (2007) who suggested that typical ageing could serve as a useful heuristic for guiding the search for the neuro-cognitive underpinnings of memory difficulties in ASD. The increasing reliance on task support in older age, along with a decline in the use of effective organisational strategies such as category clustering to facilitate memory, is thought to reflect a deterioration of the functional integrity of executive functions that are generally agreed to involve the frontal lobes (Gershberg & Shimamura, 1995) and which have also been implicated in ASD (e.g., Hill, 2004; Minshew & Goldstein, 1998). When Bowler, Gaigg and Gardiner (2010) directly examined parallels between the memory profile seen in frontal lobe pathology and ASD, however, they found only minimal support for diminished frontal functioning, raising the possibility that similarities between ASD and TD OA are more indicative of a decline in medial-temporal lobe functions that are thought to underpin the relative difficulties older adults experience in remembering associations among items rather than single items (Eichenbaum, 2004).

The aim of the present study was to test the hypothesis that ASD is characterised by relatively specific difficulties in relational but not item memory and that such difficulties resemble those observed in typical ageing. For the current study we drew on a paradigm from the amnesia literature in which participants were asked to study abstract shape triplets (Konkel, Warren, Duff, Tranel and Cohen, 2008). Konkel and colleagues (2008) compared participants' performance on 1 item and 3 relational memory tests that assessed memory for either the shapes making up the triplets, the screen-locations, their order or combinations of the shapes (hereafter ‘associative memory’) presented at study. In that study 10 typical individuals (matched to the patient groups on gender, age and education) were compared to a group of 4 individuals who presented a specific hippocampal lesion (M_{age} = 49.25, age range: 44-56 years) and a group of 3 people who showed a larger lesion of the medial temporal lobes (MTL) including the hippocampus but extending into the surrounding cortical areas (in 2 patients the lesion extended beyond the MTL, M_{age} = 53.33, age range: 49-58 years). For the 10 typical individuals, they found that the 3 relational memory tasks were significantly more difficult than the item test. Comparing the 2 patient groups it was found that patients with extensive MTL lesions performed at chance on all relational tasks as well as on the item task whereas patients with lesions restricted to the hippocampus performed above chance on the item but not the relational tasks. No direct comparison between control group and hippocampal patient group was presented. When both patient groups together were compared to the typical group, it was found that patients showed significantly lower performance than the typical group on all 4 tasks. In line with a large body of literature (see Eichenbaum, 2004; Eichenbaum, Yonelinas & Ranganath 2007; Mayes, Montaldi & Migo, 2007 for reviews), the results of this study suggested that the hippocampus is critical for relational but not item memory processes whereas the wider MTL including cortical areas surrounding the hippocampus (particularly the parahippocampal and perirhinal cortices) additionally support item memory.

The paradigm developed by Konkel and colleagues (2008) has several advantages over other experimental tasks hitherto employed to examine the neuro-cognitive underpinnings of memory in ASD. First, it compares different kinds of relational memory (order and locations of item presentation and associations between items) using the same paradigm. This is important in order to establish whether or not particular kinds of relational information prove more or less of a challenge for ASD individuals. In addition it compares these kinds of relational memory to item memory using the same paradigm to establish whether or not item memory is relatively preserved. Usually item memory is tested using somewhat different procedures from those used to test relational memory and one could argue that item tests are usually less complex (fewer discrete units of information presented). This is problematic for a direct comparison between item and relational memory, especially if one considers ASD to be a disorder of complex information processing (Minshew & Goldstein, 1998). Second, the use of stimuli that are not easy to label verbally, minimises potential group differences in the use of verbal strategies, including the use of sub-vocal and inner speech strategies that have been shown to operate differently in ASD (Williams, Bowler & Jarrold, 2012). Finally, the use of novel abstract shapes minimises the influence of pre-existing experiences that individuals might have had with the stimuli and that might differ between groups.

We implemented a few changes to the paradigm. First, rather than coloured shapes we used black shapes presented on a grey background (see Figure 1) because a recent review of vision in ASD (Simmons et al., 2009) indicated that ASD individuals might have difficulties in remembering/ discriminating between different colours compared to TD individuals. These shapes have been used previously in another clinical population (Haenschel et al., 2007) and had been generated with a Matlab algorithm to achieve a comparable level of complexity. Second, we also changed presentation time, number of images and task instructions (for further details, see methods section).

Drawing on the relational memory account (Bowler et al., 2011) we expected ASD individuals to show a similar performance to Konkel and collagues' (2008) hippocampal patient group with lower performance compared to the comparison group especially in the relational memory tests. In addition we expected intact performance for the ASD group on the item test. Relating to the ageing analogy (Bowler, 2007) only one study has so far investigated age-related memory changes in older ASD individuals (Geurts & Vissers, 2012). They found that visual memory decreased with age for TD and ASD individuals but more so for ASD individuals. Since the participants were somewhat older than the participants in the current study, we based our predictions on the ageing analogy expecting ASD individuals' memory performance to be similar to that of the older participants in our TD group. For this analysis we focussed on the order task. Order memory has been shown to be particularly sensitive to frontal function decline (Shimamura, Janowsky & Squire., 1990) and is therefore most sensitive to age-related memory decline (Blachstein, Greenstein & Vakil, 2012), as in typical ageing frontal lobe functions decrease first which are later on followed by functions mediated by the medial temporal lobes (Hedden & Gabrieli, 2004).

Methods

Participants

Eighteen TD individuals (14 men, 4 women, M_{age} = 43.48 years, age range: 23-61 years) and 18 ASD individuals (13 men, 5 women, M_{age} = 42.78 years, age range: 20-62 years) participated in this study. Participants were individually matched on Verbal IQ (VIQ), Performance IQ (PIQ) and Full-scale IQ (FIQ) as measured by the third edition of the Wechsler Adult Intelligence Scale (WAIS-III^{UK}; The Psychological Corporation, 2000). Groups were closely matched on gender and chronological age (see Table 1). FIQ was above 70 and below 140 for participants in both groups and therefore within the normal range excluding individuals with a learning difficulty. Participants in both groups were randomly selected from a panel of people with whom the Autism Research Group is in regular contact. All ASD individuals were diagnosed with an Autism Spectrum Disorder (DSM-IV-TR, American Psychiatric Association, 2000) by psychiatrists or clinical psychologists experienced in diagnosing ASD. A review of diagnostic records was undertaken to ensure that participants fulfil DSM-IV-TR criteria for an ASD. The main inclusion criterion was that individuals had a clinical diagnosis of an ASD. Time permitted to get further support for a clinical diagnosis for 15 out of 18 subjects with an Autism Diagnostic Observation Schedule (ADOS; Lord et al., 1989) which was administered by individuals trained to research reliability standards and confirmed difficulties in reciprocal social communicative behaviours that are the hallmark of the disorder. TD individuals were only included in the study if they did not report taking psychotropic medication or an own or family history of a neuropsychological or developmental disorder including ASD. All participants were reimbursed for their time and travel expenses according to standard university fees. This study was approved by the ethics committee of the Psychology Department of City University London and the procedures used in this study adhered to the guidelines set out by the British Psychological Society.

[Insert Table 1 here]

Materials

The paradigm used was an adaptation of that used by Konkel and colleagues (2008). Participants took part in 4 tasks, which consisted of 8 (item, location, order task) or 12 (associative task) study-test blocks. Materials were 356 (8 for practice task) black shapes presented on a grey square measuring 5.3 x 5.3 cm on a 20 inch desktop monitor. The colour of the screen background was white (see Figure 1). The study phase was the same for all 4 tasks. Participants studied 3 unique sets of abstract shape triplets, chosen at random from a master set of 240 stimuli. The individual shapes comprising a particular triplet were presented in succession in each of 3 screen-locations: top left, top right and bottom middle of the screen. The order of these locations was counterbalanced across triplets such that each location was once the first, second and third location to be occupied by a shape across the 3 study triplets. Each item set was presented once, with a presentation time of 4s for each item and a 2s blank screen following each triplet. After presentation of the 3 study triplets, participants were given 2 or 3 test trials (depending on the task) in which items were presented together with a test question, which remained on the screen until participants gave their response. In the test trials, participants were presented with either repeated or manipulated test trials. The order of repeated and manipulated test trials was counterbalanced across the 8 blocks (12 for the associative test) so that participants were given 12 repeated and 12 manipulated tests for every task in total. For a more detailed description of the tasks see Konkel and colleagues (2008).

[Insert Figure 1 here]

Procedure

Stimuli were presented on a computer screen using E-Prime software. Participants were asked to indicate their response by pressing the appropriate key on the keyboard in front of them. Prior to the start of the experiment informed consent was obtained and participants were given a practice task to familiarise them with the procedure. The practice was presented in the form of an item task with two shape triplets presented in the study phase and 1 repeated and 1 manipulated test trial. Participants were given the chance to ask questions. They were also told that the task was quite difficult and they were encouraged to take as many breaks as they needed. Every participant was then given an item test as the first task. This was because we wanted participants to focus on the items and not to be influenced by a strategy they had used for one of the relational tasks. The order of the 3 relational memory tests that followed was counterbalanced across participants with each pair of matched participants receiving the same order of presentation.

For the *item test* participants were instructed to focus on the items during study. Before the test, they were told that if they had seen all 3 items in the study phase they should press letter “y” for yes on the keyboard. If 1 or 2 of the items felt new to them, they were asked to press “n” for no. For the *locations task* participants were asked to focus on the locations of the items on the screen for the *associative task* to pay attention to which 3 pictures were presented together as a triplet and for the *order tes*t to focus on the order in which items appeared at study. For all of these relational tests, they were told that none of the items would be new and they were instructed to press “y” for yes if the relations were the same as at study (pictures in same locations, same order, same combinations of shapes) and to press “n” for no if relations had changed (swapped locations, altered order or re-combined triplets of shapes). Total task duration (in minutes) including breaks did not differ significantly between ASD (*M* = 79.39, *SD* = 47.19) and TD (*M* = 66.28, *SD* = 16.41) groups, *t*(34) = -1.11, *p* = .27, Cohen’s *d* = 0.37, CI (-0.30, 1.02).

Results

The raw data were scored in terms of hit rates (percentage correct), false alarm rates (percentage incorrect) and corrected hit rates/ corrected recognition (hits minus false alarms). Hit rates and false alarm rates were used to calculate d’ (presented in Table 2 to enable a comparison to the data reported by Konkel et al., 2008). Results were analysed using Chi-Squared tests, one sample and independent samples t-tests and repeated measures ANOVAs. Greenhouse Geisser correction (GGC) was used when the Sphericity assumption was violated. In addition bivariate correlations and a regression were calculated. The level of significance was set to .05.

Correct recognition (Hits)

The data are presented in Table 2. Hit rates were entered into a 4 (Task [item, location, order, associative]) x 2 (Group [ASD, TD]) repeated measures ANOVA. No significant main effects for Task, $F(3,102) = 1.97$, $p = .12$, $\eta_p^2 = .06$, or Group, $F(1,34) = 1.91$, $p = .18$, Cohen's $d = 0.39$, CI (-0.28, 1.04), nor a significant interaction between Task and Group, $F(3,102) = 0.02$, $p = 1$, $\eta_p^2 = .00$, could be found.

False alarms (FA)

False alarm rates are presented in Table 2 and were analysed using a 4 (Task [item, location, order, associative]) x 2 (Group [ASD, TD]) repeated measures ANOVA. There was a significant main effect of Task, $F(2.42,82.29) = 12.20$, $p < .001$, $\eta_p^2 = .26$, GGC, with significantly higher false alarm rates in the associative task compared to all other tasks, item- $p < .001$, Cohen's $d = 0.81$, CI (0.32, 1.28); location- $p < .01$, Cohen's $d = 0.72$, CI (0.23, 1.19); order- $p < .05$, Cohen's $d = 0.45$, CI (-0.02, 0.91), and a significant main effect of Group, $F(1,34) = 8.46$, $p < .01$, Cohen's $d = 0.76$, CI (0.07, 1.42), with higher false alarm rates for the ASD compared to the TD group. No Task x Group interaction could be found, $F(2.42,82.29) = 1.67$, $p = .19$, $\eta_p^2 = .05$, GGC. However, it is worth noting that the effect sizes for group differences between the relational tasks, especially the location and order tasks were much larger than the effect size for the group difference for the item task (see Table 2) indicating greater difficulties in the ASD group with the relational tasks.

Corrected recognition (Hits-FA)

The data for corrected recognition rates are set out in Table 2. They were entered into a 4 (Task [item, location, order, associative]) x 2 (Group [ASD, TD]) repeated measures ANOVA. A significant main effect of Task, $F(3,102) = 9.51$, $p < .001$, $\eta_p^2 = .22$, was found with higher performance in the item compared to the order, $p < .05$, Cohen's $d = 0.50$, CI

(0.02, 0.96), and the associative tasks, $p < .001$, Cohen's $d = 0.89$, CI (0.40, 1.37), and higher performance for the location compared to the associative task, $p < .05$, Cohen's $d = 0.55$, CI (0.08, 1.02). A significant main effect of Group, $F(1,34) = 12.66$, $p < .01$, Cohen's $d = 0.88$, CI (0.18, 1.55), was detected with higher performance overall for the TD compared to the ASD group. There was no Group x Task interaction, $F(3,102) = 0.64$, $p = .59$, $\eta_p^2 = .02$, although inspection of between-group effect sizes suggested greater differences for the location task compared to the item task (Table 2). Due to the difficulty level of the tasks we compared both groups performance against chance performance. For corrected recognition rates, performance at chance level would not be significantly above 0. That is because corrected recognition is calculated by subtracting false alarm rates (chance level 0.5) from hit rates (chance level 0.5 and 0.5-0.5 = 0). Importantly, the performance of the TD group was above chance in all 4 tasks but the performance of the ASD group was at chance in the order, $t(17) = 1.51$, $p = .15$, and the associative task, $t(17) = 1.47$, $p = .16$, suggesting that floor level performance in these conditions by the ASD group may have masked what might otherwise have led to a significant Group x Task interaction.

[Insert Table 2 here]

Correlations among tasks

The data for correlations among task performance are presented in Table 3. Analysing both groups together showed high positive correlations between the item task and each of the relational tasks as well as among all the relational tasks, indicating that better performance on one task was related to better performance on the other tasks. However, when analysing the two groups separately results indicated that these correlations were mainly driven by the TD group's performance. Despite the smaller sample size we still found (marginally) significant correlations between all relational tasks and between the item test and all relational tasks. By contrast, there were only few correlations among the relational tasks in the ASD group. In addition there were no significant correlations between the relational tasks and the item task for the ASD group. We then calculated the significance of the difference between correlation coefficients for the two groups indicating that the correlations were all marginally significant or significantly higher for the TD compared to the ASD group, except for the one between order and associative task, which was not significantly different between the two groups.

[Insert Table 3 here]

Analysis of age-related effects on memory

To investigate the ageing analogy we used a regression analysis to see how much variance in corrected recognition rates (hit rates minus false alarm rates) was explained by age. The regression analysis showed that age did not significantly explain variance in the corrected recognition scores for the item, $R^2 = .00$, 95% CI (-0.29, 0.17), $F(1,34) = 0.15$, $p = .71$, location, $R^2 = .02$, 95% CI (-0.37, 0.09), $F(1,34) = 0.76$, $p = .39$, or the associative task, $R^2 = .01$, 95% CI (-0.31, 0.15), $F(1,34) = 0.27$, $p = .61$, for the group as a whole. By contrast, age significantly explained 11.2% of the variance, $R^2 = .112$, 95% CI (-0.53, -0.11), $F(1,34) = 4.31$, $p = .046$, and significantly predicted corrected recognition rates in the order task ($\beta = -.34$, $p < .05$) for the group as a whole. Closer inspection of the data showed that this effect only held for the TD but not for the ASD group. Age did not significantly explain any variance in corrected recognition in the order task for the ASD group, $R^2 = .01$, 95% CI (-0.39, 0.26), $F(1,16) = 0.09$, $p = .77$, but significantly explained 34.6% of the variance in corrected recognition in the order task for the TD group, $R^2 = .35$, 95% CI (-0.77, -0.32), $F(1,16) = 8.47$, $p = .01$. Age also significantly predicted performance on the order task for the

TD group, β = -.59, p = .01, (see Figure 2 for illustration). This shows that younger TD participants performed significantly higher than younger ASD and older TD individuals. However, the older participants in both groups became, the more similar their task performance was. This was related to a lower level in task performance in the TD group but memory in older ASD individuals was at similar level as that of younger individuals in this group.

[Insert Figure 2 here]

Discussion

The first aim of this study was to test the relational account of the memory difficulties seen in ASD (Bowler et al., 2011). Therefore we aimed to see if ASD individuals show difficulties with memory for location, order and set in which shape triplets were presented. Because it is known that relational memory processes change over the typical lifespan, particularly in later decades (Naveh-Benjamin, 2000), and because even younger adults with ASD have a similar memory profile to healthy TD OA (see Bowler, 2007), our second aim was to investigate how relational memory changes with age in both groups.

Referring to relational memory, our prediction of decreased relational memory in ASD was confirmed. We found a significantly lower performance in the ASD group for the three relational memory tasks. The effect size of the difference in the locations (Cohen's d = 1.19) task was larger than the effect size of the item test (Cohen's d = 0.83). In addition ASD individual's performance was at chance for the order and associative tasks. Taken together this suggests that ASD individuals seem to have struggled more in the relational memory tests. Therefore, our results replicate earlier findings of difficulties with memory for locations in ASD (Bowler et al., 2014; Ring et al., under review) and extend those findings from everyday objects to abstract shapes. Our ASD group also resembles Konkel and colleagues' (2008) hippocampal patients who showed significantly lower performance on all tasks compared to TD individuals but especially lower performance on the relational memory tasks. This parallel gives strong support to the notion of relational memory difficulties (Bowler et al., 2011) in ASD, which are known to involve hippocampal functions (Opitz, 2010). However, it is worth noting that individuals with hippocampal lesions performed at chance on all the relational tasks whereas our ASD group performed significantly above chance in the item and the location tests suggesting that they were less impaired than hippocampal patients, but such conclusions need to be drawn with caution because the two groups were not compared directly in the same study. In addition Konkel and colleagues (2008) only tested 4 individuals with hippocampal lesions resulting in low power and noisy data.

Regarding item memory, our prediction of spared item memory in ASD was not supported. We found significantly lower performance for the ASD group compared to the TD group in the item task, conflicting with the notion of relatively preserved item memory in ASD (Bowler et al., 2011). One reason for this finding could be that the item test was of similar complexity to the relational memory tasks. It has been suggested that ASD individuals show difficulties with increased complexity (Minshew & Goldstein, 1998). The present finding is also in line with previous research on item memory showing impaired performance in ASD when the task facing participants involved memorising source information in addition to memorising words (Bowler et al., 2004) or pictures (Semino et al., 2013). Bowler and colleagues (2004) asked participants to also remember where on the screen the word appeared or to remember the gender of the speaker who read out the word. Semino and colleagues (2013) asked participants to memorise a picture of an object and which location on the screen the object originated in. Together with this earlier work, our findings suggest circumstances under which even item memory is compromised in ASD. In relation to this it is interesting that we found high correlations in the TD group between item and relational tasks but not in the ASD group. This suggests that even when care is taken to experimentally dissociate item from relational memory, the processes contributing to performance are intertwined at least in the TD group. TD individuals may have drawn on relational processes even in the item test (e.g. because preserved relational memory provided enough flexibility to recognise items presented simultaneously rather than sequentially). However, ASD individuals did not have these flexible relational processing skills and could therefore not rely on them to support item test performance. Therefore it would be advisable to run another study comparing explicit item and relational memory instructions for TD and ASD individuals. Such a study would indicate if training and possible intervention strategies might be feasible to alleviate relational memory difficulties in ASD.

There are a few *caveats* on the present findings that need to be addressed in future research. First, in the current tasks, the TD group performed at a relatively low level in the order and associative tasks and ASD individuals performed at chance on these tasks. This is in line with the finding of Konkel and colleagues (2008). However, in order to enable a fairer comparison between TD and ASD, easier tasks should be used. The use of easier tasks might also enable a better comparison between the different types of relations to establish which ones might be more or less difficult for ASD individuals. In the current study the largest effect size was found for the group difference in the locations task suggesting that this might be the hardest for ASD individuals. The group difference between order and associative task was about the same size as that of the item task. There are 2 possible reasons for this pattern of results: either these tasks were less difficult for ASD individuals or the group difference was obscured because the tasks were also more difficult for TD individuals. Konkel and Cohen (2009) have suggested that all relations seem to rely to the same extent on the hippocampus. So if ASD individuals have difficulties with hippocampal functions there should not be a difference between different relations. However, it is also possible that some relations can be got around more easily by means of compensatory strategies making them easier for ASD individuals. Following from that ASD individuals might have particular difficulties with space, which needs to be tested in further research. In relation to that it is interesting to note that high correlations between the relational tasks suggest that the TD group seems to have relied on similar cognitive processes for all tasks. The absence for correlations in the ASD group needs to be considered with caution since their performance is at chance in the order and associative tasks. However, the absence of any correlation between item and location task in ASD suggests that they seem not to have used the same cognitive processes for the two tasks.

The second *caveat* is that the present study was purposefully run with abstract shape material. In order to be able to generalise the findings they would need to be replicated with meaningful verbal or pictorial material to test whether the addition of language might make the tasks more difficult for ASD individuals or whether it would make memorising and retrieving the relations easier.

Regarding our second aim, based on Bowler's (2007) identification of a similarity of patterning of memory in healthy ageing and ASD, we predicted similar performance of the ASD group compared to TD OA. This prediction was confirmed. We found strong age-related effects on memory in TD individuals but not ASD individuals. Older TD individuals' memory performance was much worse than younger TD individuals' performance. But ASD individuals' performance was similar for older and younger individuals of this group regardless of age. For both groups in comparison that means that younger individuals with ASD performed worse than age-matched TD participants but older ASD individuals' performance was similar to that of older TD individuals. By suggesting individuals with ASD have similar memory difficulties to older TD individuals, this evidence provides strong support for the ageing analogy (Bowler, 2007). Factors underlying memory decline in older TD adults might operate at an earlier age in ASD individuals. Hippocampal and frontal lobe/ executive function atypicalities seem to be involved in memory difficulties in ASD. Considering that ASD is a developmental disorder it is likely that certain brain regions and their functions develop at different rates or only up to a certain degree. If the finding of the current research is a result of an earlier decline in ASD or a different developmental trajectory altogether remains uncertain and needs to be systematically investigated in future research. In addition this finding needs to be replicated with different paradigms and materials.

Considering the parallel between memory performance in ASD and that of TD OA it would be worth testing whether memory strategies that have been shown to be effective in improving memory in TD OA (e.g. Naveh-Benjamin, Brav & Levy, 2007) might also be of benefit in helping to improve ASD individuals' memory performance in both younger and older participants. Further, it would be important to study what happens to ASD individuals' memory and cognitive functioning after the age of 60 years. In TD OA, increasing age is related to a decrease in hippocampal function and memory loss (Hedden & Gabrieli, 2004). There is only one study so far investigating age-related memory changes in ASD which suggests a more rapid decrease in visual memory in ASD compared to the TD group with increasing age (Geurts & Visser, 2012). As this is only one study with a relatively small sample and a specific task more research is needed to see if this finding can be replicated with other larger samples and tasks.

In conclusion the present study lends further support to Gaigg and colleagues (2008) finding of relational memory difficulties in ASD by extending it to different kinds of relations. The findings also lend support for the idea of a parallel between order memory difficulties in ASD and in older TD individuals.

Acknowledgements

We are grateful to Dr. Corinna Haenschel for providing the shape stimuli used in this experiment and would like to thank all the participants who have taken part in this research.

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Table 1. *Descriptive statistics for Autism Spectrum Disorder (ASD) and typically developing (TD) individuals*

	TD (14m, 4f)		**ASD (13m, 5f)**					
	M	***SD***	***M***	***SD***	***t*(34)**	***p***	**Cohen's *d***	**CI**
Age (years)	43.48	13.0	42.78	11.8	0.17	.87	0.06	-0.60, 0.71
VIQ[a]	111	15.6	109	15.8	0.47	.64	0.13	-0.50, 0.81
PIQ[b]	105	18.0	104	20.1	0.06	.95	0.05	-0.63, 0.67
FIQ[c]	109	17.2	108	17.9	0.29	.77	0.06	-0.56, 0.75
ADOS-C[d]			2.60	1.64				
ADOS-RSI[e]			6.00	3.32				
ADOS-Total[f]			8.60	4.10				
ADOS-I[g]			1.27	0.80				
SB[h]			1.2	0.94				

Note. [a]Verbal IQ (WAIS-III[UK]). [b]Performance IQ (WAIS-III[UK]). [c]Full-scale IQ (WAIS-III[UK]). [d]ADOS- Communication subscale. [e]ADOS- Reciprocal Social Interaction subscale. [f]ADOS Total score- Communication+Reciprocal Social Interaction. [g]ADOS- Imagination/ Creativity subscale. [h]Stereotyped Behaviours and Restricted Interests.

Table 2. *Means (M) and Standard deviations (SD) for Hits, false alarm rates, corrected Recognition (Hits- false alarms) and d' for both groups. T, p, effect sizes (Cohen's d) and 95% confidence intervals (CI) are presented for the between group differences.*

Measure	**TD** *M* (*SD*)	**ASD** *M* (*SD*)	**Both** *M* (*SD*)	***t*(df)**	***p***	**Cohen's *d***	**CI**
Hit rates	0.60	0.51	0.55				
	(0.21)	(0.23)	(0.23)				
Item task	0.65	0.56	0.60	.24			
	(0.18)	(0.27)	(0.23)	(34)	.24	0.40	-0.27, 1.05
Location task	0.58	0.50	0.54	.21			
	(0.21)	(0.18)	(0.20)	(34)	.21	0.44	-0.23, 1.09
Order task	0.57	0.49	0.53	.35			
	(0.27)	(0.22)	(0.25)	(34)	.35	0.32	-0.35, 0.97
Associative task	0.58	0.50	0.54	.24			
	(0.17)	(0.26)	(0.22)	(28.92)	.24	0.40	-0.27, 1.05
False alarms	0.21	0.36	0.29				
	(0.19)	(0.22)	(0.22)				
Item task	0.15	0.28	0.22	-1.74			
	(0.20)	(0.23)	(0.22)	(34)	.09	0.58	-0.10, 1.23
Location task	0.14	0.35	0.24	-3.57			
	(0.13)	(0.21)	(0.20)	(27.88)	.001	1.19	0.46, 1.87
Order task	0.20	0.39	0.29	-3.12			
	(0.16)	(0.22)	(0.21)	(34)	.004	1.04	0.32, 1.71
Associative task	0.34	0.44	0.39	-1.37			

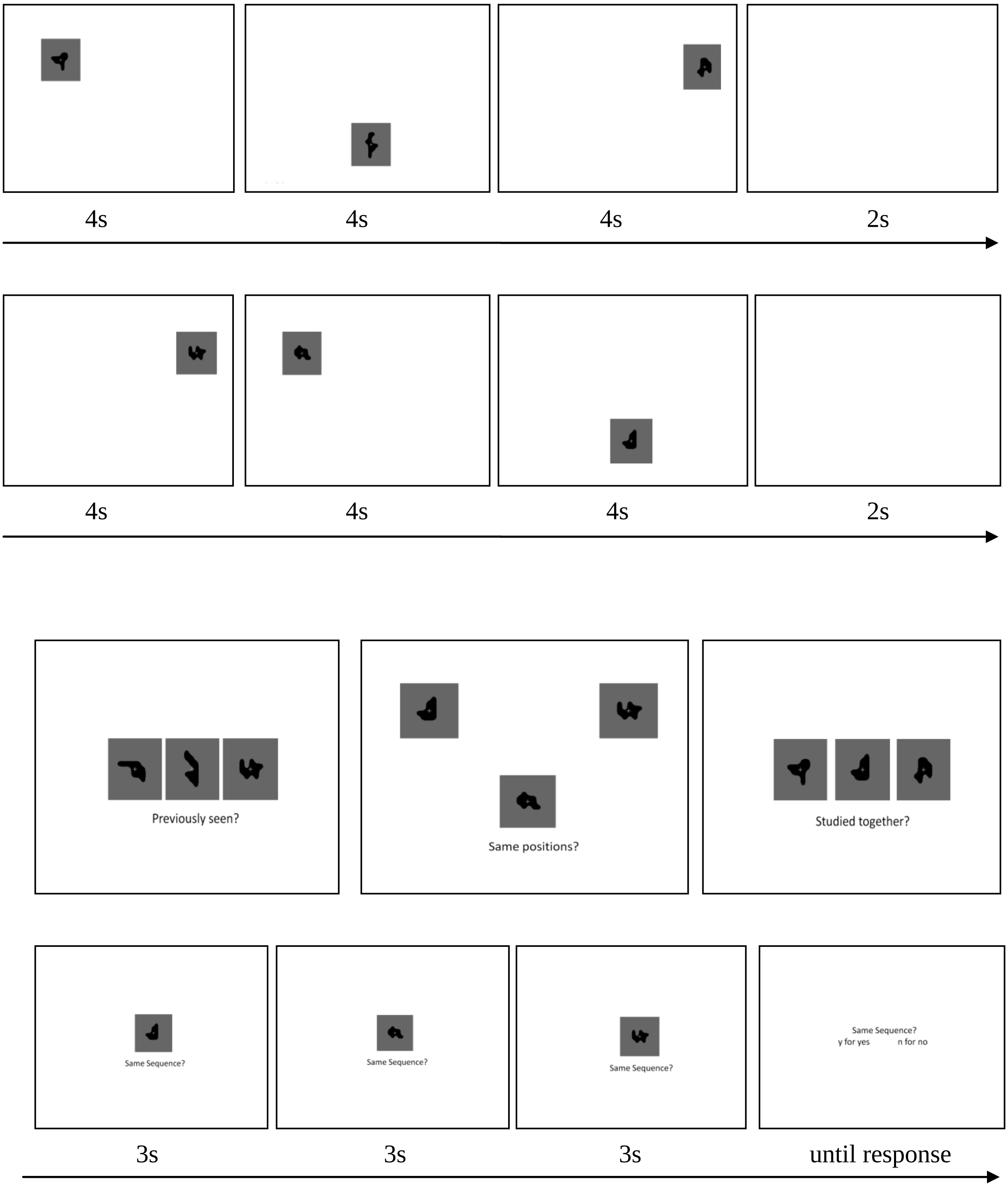
	(0.19)	(0.22)	(0.21)	(34)	.18	0.45	-0.22, 1.11
Corrected	0.39	0.15	0.27				
Recognition	(0.31)	(0.23)	(0.30)				
Item task	0.50	0.28	0.39	2.50			
	(0.30)	(0.22)	(0.28)	(34)	.02	0.83	0.13, 1.49
Location task	0.44	0.15	0.30	3.59			
	(0.25)	(0.23)	(0.28)	(34)	.001	1.19	0.46, 1.87
Order task	0.37	0.09	0.23	2.66			
	(0.36)	(0.26)	(0.34)	(34)	.01	0.89	0.19, 1.55
Associative task	0.24	0.06	0.15	2.32			
	(0.28)	(0.17)	(0.25)	(28.29)	.03	0.78	0.08, 1.44
d’	1.93	0.54	1.23				
	(2.05)	(0.94)	(1.73)				
Item task	2.87	0.96	1.91	3.53			
	(2.09)	(0.96)	(1.88)	(23.81)	.002	1.17	0.44, 1.85
Location task	1.97	0.45	1.21	3.53			
	(1.68)	(0.72)	(1.49)	(23.06)	.002	1.18	0.45, 1.86
Order task	1.86	0.59	1.23	1.90			
	(2.54)	(1.27)	(2.08)	(25.01)	.07	0.63	-0.05, 1.29
Associative task	1.00	0.15	0.57	2.40			
	(1.41)	(0.50)	(1.13)	(21.25)	.03	0.81	0.11, 1.46

Table 3. *Correlations between corrected recognition rates for all 4 tasks for both groups as a whole as well as both groups separately. Below the significance of the difference between the correlation coefficients for the 2 groups.*

	TD			ASD			Both		
Task	**2**	**3**	**4**	**2**	**3**	**4**	**2**	**3**	**4**
3	.75** (0.56, 0.86)			.44+ (0.14, 0.67)			.70** (0.56, 0.80)		
4	.45+ (0.15, 0.68)	.48* (0.18, 0.70)		.01 (-0.32, 0.34)	.56* (0.28, 0.75)		.42* (0.21, 0.59)	.58** (0.40, 0.71)	
1	.68** (0.46, 0.83)	.60** (0.34, 0.77)	.55* (0.27, 0.74)	.14 (-0.19, 0.45)	.20 (-0.15, 0.49)	.13 (-0.21, 0.44)	.57** (0.39, 0.71)	.55** (0.36, 0.69)	.50** (0.31, 0.66)

	z	***p***
1-2	1.88	< .05
1-3	1.36	.087
1-4	1.35	.089
2-3	1.35	.089
2-4	1.30	.097
3-4	-0.3	.38

Note. 1 = item test. 2 = location test. 3 = order test. 4 = associative test. + $p < .1$. * significant at $p < .05$. ** significant at $p \leq .01$. The 95% confidence interval (CI) is presented in brackets.


4s
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Previously seen?
Same positions?
Studied together?
Same Sequence?
Same Sequence?
Same Sequence?
Same Sequence?
y for yes
n for no
3s
3s
3s
until response

Figure 1. Examples of 2 study trials (top) and examples for manipulated test trials (middle and bottom). Figure 1a (middle left) shows a manipulated item test trial presenting 1 item from study trial 2 with 2 previously unseen items. Figure 1b (middle middle) shows a manipulated location test trial presenting the images from study trial 2 but the images top left and bottom middle have swapped their locations. Figure 1c (middle right) shows a manipulated associative test trial presenting 2 of the images from study trial 2 intermixed with 1 image from trial 1. Figure 1d (bottom) shows a manipulated order/ temporal sequence test trial presenting the images from study trial 2 but the first and the third image have swapped their positions in the sequence.

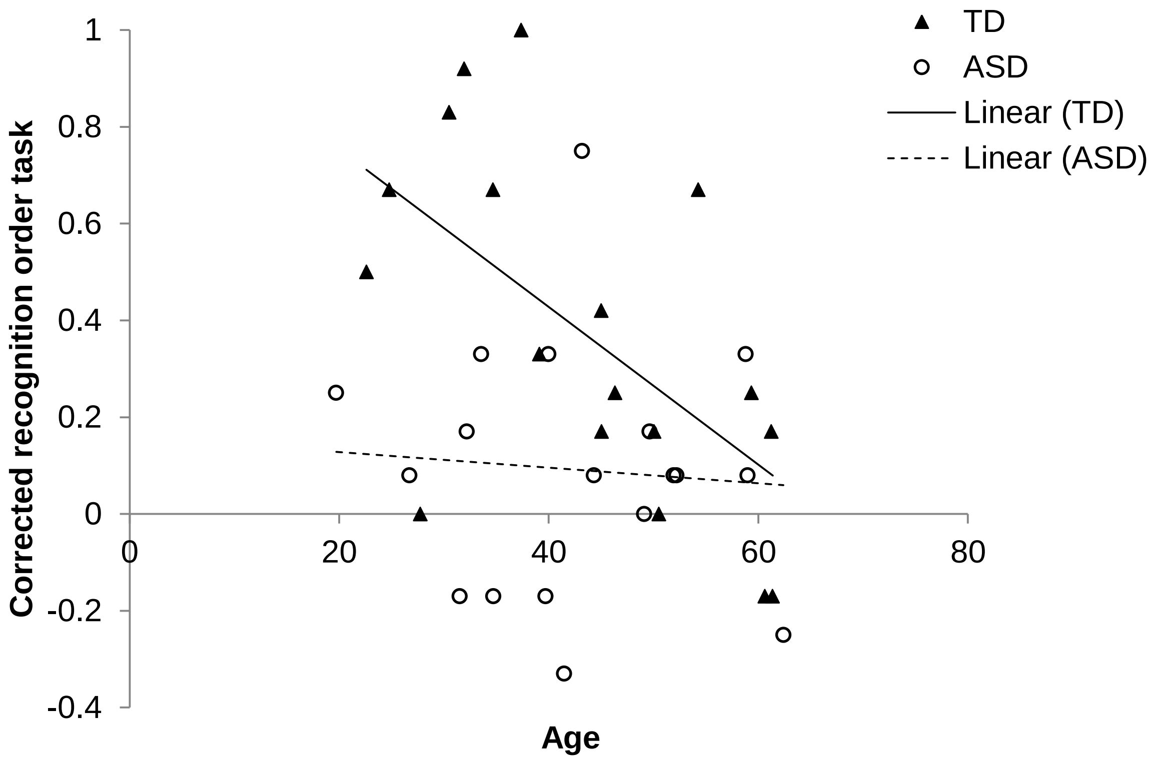

Figure 2. Regression with age for corrected recognition rates for the order task comparing ASD and TD group.