

Manuscript Number:

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Article Type: Research Paper

Keywords: Williams Syndrome; ageing; cognition; episodic memory; semantic memory; depths of processing; encoding

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Abstract: Previous research exploring declarative memory in Williams syndrome (WS) has revealed impairment in the processing of episodic information accompanied by a relative strength in semantic ability. The aim of the current study was to extend this literature by examining how relatively spared semantic memory may support episodic remembering. Using a level of processing paradigm older adults with WS (aged 36 - 61 years) were compared to typical adults of the same chronological age and typically developing children matched for verbal ability. In the study phase, pictures were encoded using either a deep (decide if a picture belongs to a particular category) or shallow (perceptual based processing) memory strategy. Behavioural indices (reaction time and accuracy) at retrieval were suggestive of an overall difficulty in episodic memory for WS adults. Interestingly, however, semantic support was evident with a greater recall of items encoded with deep compared to shallow processing, indicative of an ability to employ semantic encoding strategies to maximise the strength of the memory trace created. Unlike individuals with autism who find semantic elaboration strategies problematic, the pattern of findings reported here suggests in those domains that are relatively impaired in WS, support can be recruited from relatively spared cognitive processes.

Highlights

- We examine how semantic memory enhances episodic remembering in adults with WS
- Unlike individuals with autism, older adults with WS can benefit from depths of processing
- Relative strengths in semantic memory compensate for deficits in episodic memory
- Experimental work here provides the groundwork for semantic elaboration strategies

Depths of Memory Processing in Adults with Williams syndrome

Deeper processing is beneficial during episodic memory encoding for adults with Williams syndrome

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Abstract

Previous research exploring declarative memory in Williams syndrome (WS) has revealed impairment in the processing of episodic information accompanied by a relative strength in semantic ability. The aim of the current study was to extend this literature by examining how relatively spared semantic memory may support episodic remembering. Using a level of processing paradigm older adults with WS (aged 36 – 61 years) were compared to typical adults of the same chronological age and typically developing children matched for verbal ability. In the study phase, pictures were encoded using either a deep (decide if a picture belongs to a particular category) or shallow (perceptual based processing) memory strategy. Behavioural indices (reaction time and accuracy) at retrieval were suggestive of an overall difficulty in episodic memory for WS adults. Interestingly, however, semantic support was evident with a greater recall of items encoded with deep compared to shallow processing, indicative of an ability to employ semantic encoding strategies to maximise the strength of the memory trace created. Unlike individuals with autism who find semantic elaboration strategies problematic, the pattern of findings reported here suggests in those domains that are relatively impaired in WS, support can be recruited from relatively spared cognitive processes.

INTRODUCTION

Williams syndrome (WS) is a neurodevelopmental disorder with an estimated prevalence of 1:20,000 live births (Morris & Mervis, 2000). Although there is significant heterogeneity of cognitive function, individuals with WS tend to function at the level of mild-moderate intellectual difficulty (Searcy et al., 2004). The disorder has attracted the attention of cognitive scientists primarily due to the distinctive cognitive profile (Meyer-Lindenberg, Mervis, & Berman, 2006). A wealth of literature has documented relatively impaired non-verbal and visuo-spatial skills (e.g. Jarrold, Baddeley, & Phillips, 2007; Vicari, Bellucci, & Carlesimo, 2005) compared with relative strengths in the verbal domain (Brock, 2007). This profile occurs against the general backdrop of cognitive impairment. Relative strength in the verbal domain is mirrored behaviourally, as individuals with WS (both children and adults) tend to be highly-sociable, exhibiting a strong desire to converse with others, clear verbal articulation skills, and speech fluency (Udwin, Yule, & Martin, 1987). However, these verbal abilities are far from 'intact' and the development of language is far from 'typical'. Rather, the social demeanour shown by some individuals with WS may give a misleading impression of competence and ability, masking the extent of subtle communication atypicalities and language impairments. In a manner similar to the subtle atypicalities that characterise WS language, the spatial skills of individuals with WS not only show a general inaccuracy, but are characterised by subtle atypicalities in processing style, especially a deficit linking information into a coherent whole (Deruelle, Rondan, Mancini, & Livet, 2006). A neglected aspect of the WS cognitive profile is declarative memory and in particular how the component parts of this system, namely episodic and semantic memory interact to produce rich and coherent long-term memory representations.

Not only is the ability to make an association between extracts of information particularly problematic for many individuals with WS (Costanzo, Vicari, & Carlesimo, 2011), it is also a key attribute of episodic memory ability. Long-term episodic memory can be defined as the ability to remember rich details of previously encountered events, which would include not only memory for items but also any accompanying associations and contextual details. Devenny et al. (2004) examined episodic and working memory in adults with WS compared to controls (developmental disability with unspecified aetiology). Using a free-recall paradigm, episodic memory was found to be impaired relative to controls and, importantly, age predicted the degree of impairment in the WS group. The lack of difficulty in the working memory domain led the authors to argue for specific problems in memory requiring the need to retrieve rich associative and contextual information. The data were also consistent with the ‘accelerated ageing’ hypothesis in WS, with a greater deficit in the older adults who had the disorder (mean 48.3 years of age). The suggestion that the cognitive decline emulates the pattern seen in ‘normal’ ageing would be consistent with impaired episodic compared to semantic memory, albeit with the decline occurring chronologically earlier.

Neuroimaging and studies examining other neurodevelopmental disorders have been informative regarding possible similarities in the profiles of older adults who have developed typically and WS adults, showing parallels in the nature of impairments of the hippocampal region, the key substrate of episodic memory. Meyer-Lindenberg et al. (2005) used multi-modal imaging to investigate structural (MRI) and functional (PET, functional and spectroscopic MRI) integrity and found similarities in structure (although subtle differences were observed) but reductions in resting blood flow and metabolic activity of the hippocampus. The authors argued that the region is critical in the processing of spatial and

episodic information. As a final point, it is interesting to note comparisons in the neuro-cognitive profiles of Down syndrome (DS) and Williams syndrome. For example, in research comparing cognition in DS and typical development, Pennington, Moon, Edgin, Stedron, & Nadel (2003) observed exaggerated deficits in those domains of cognition sub-served by the hippocampus (e.g. pattern recognition; paired associate learning) compared to frontal lobe measures (e.g. verbal and design fluency). Therefore, evidence of atypicalities and deficits of cognition in other disorders, even without direct comparison to WS, can be informative.

The behavioural and neuroimaging evidence concerning episodic memory ability in WS therefore suggests an array of atypicalities, especially when linking information in memory. Inspection of the literature regarding the second component of declarative memory, namely semantic memory, reveals less consistency with mixed results regarding more and less proficient areas of functioning. Tests of semantic fluency are informative and tell us much about semantic organisation. In a typical experiment participants are required to generate exemplars from a particular category in a set time (for example listing apple, orange, banana as types of fruits) and WS individuals tend to produce unusual and low frequency exemplars (e.g. Bellugi, Wang & Jernigan, 1994). However, Jarrold, Hartley, Phillips, & Baddeley (2000) examined individuals with WS and vocabulary matched typical controls (arguably the most appropriate method given the nature of the tasks) on a category fluency task and examined the overall number of exemplars that were generated, how unusual the exemplars were, and grouping of semantic related responses. The findings demonstrated no evidence of the production of unusual responses. A key finding was that during the retrieval of exemplars, impairments in the monitoring of responses were evident; indexed by the number of repeated exemplars given (see Greer, Riby, Hamilton, & Riby, 2013 for a discussion of monitoring

and executive control deficits in adults with WS). Therefore, it could be hypothesised that the atypicalities associated with performance on this type of semantic task, are not linked solely to memory or language skill but link to broader aspects of the cognitive capacity and executive function (e.g. see Greer et al., 2013; Rhodes, Riby, Matthews, & Coghill, 2011).

Elsewhere, Thomas et al. (2006) examined picture naming speed (e.g. in the categories of animals, body parts and household items) as a potential measure of the speed of access to semantic memory. Overall speed of naming was slower in participants with WS. However, equivalent performance or at least similar semantic organisation could be proposed since after controlling for this basic speed measure, naming was more difficult and less frequent items were equally problematic across participant groups. Likewise, in another arguably less demanding semantic task, semantic priming and naming speed (speed of access to semantic memory as a measure) was relatively well preserved when target words were preceded by a semantically related (e.g. apple/pear) prime, compared to unrelated (e.g. house/banana) prime (Tyler et al., 1997). A further behavioural finding is noteworthy and highlights semantic strategies employed during memory retrieval rather than simple naming speed. Indeed, Bellugi et al. (1994) reported that when individuals with WS were presented with exemplars from various categories to remember, recall performance was characterised by semantic clustering of the previously studied items (grouping items from the same category) and therefore they suggested that individuals with the disorder were successfully using semantic memory to aid episodic memory performance.

The aforementioned research suggests that when long-term memory requires the encoding or retrieval of rich item and contextual information, difficulties are observed for individuals with WS. However, much like the pattern seen in the ‘normal’ ageing process, this is accompanied by relatively less difficulty with memory for more automatic, overlearned information involving semantic memory. The focus of the current study concerns whether adults with WS can benefit from semantic support, which has typically been demonstrated in a levels-of-processing paradigm (LoP; Craik & Lockhart, 1972). Given the relative proficiency of semantic memory skills are adults with WS able to use this ‘strength’ as a strategy to support more evident deficits of episodic memory processing, especially when required to link information together?

In typically developing individuals, shallow processing (e.g. focussing on perceptual / phonological components of the stimuli) leads to a fragile memory trace, since the information is less embedded in semantic memory, and as a result relatively poor subsequent recall. Deep processing (e.g. making semantically-related decisions about the stimuli) on the other hand results in a more durable memory trace and typically relatively superior recall (Craik & Lockhart, 1972). Typically developing individuals benefit from LoP across the lifespan, and it can facilitate memory improvement in older age when memory processes such as episodic memory are known to decline (Grady & Craik, 2000). The aim of the current study is therefore to extend investigations of the LoP phenomena to adults who have WS (aged 35+ years) and elucidate whether i) a generalised deficit in episodic memory is observed (which is not unreasonable to predict given the wealth of behavioural work and also neuroimaging investigation pointing to hippocampal dysfunction in adults with WS) and ii) whether semantic memory skills provide a supportive role using a LoP paradigm. We

therefore predict a supportive role will be evident by stronger performance for 'deep' rather than 'shallow' processing condition. Finally, it is worth noting that there has been a dearth of research exploring the way that episodic and semantic memory interact in typical development, let alone specific to WS. In the one relevant study that has linked these aspects and taken a LoP approach to memory in the developmental disorder autism, Toichi and Kamio (2002) failed to demonstrate a benefit of 'deeper' processing in their participants with autism. Rather, they reported superior episodic memory performance (using less efficient perceptual and rote encoding strategies) that was very different to the pattern observed in typical development. Therefore, while it is possible that this is an 'autism-specific' pattern of memory performance, it could be a characteristic of general intellectual difficulty and thus the current study would provide insight into that argument.

METHOD

Participants

A group of 20 adults with WS (35–63 years, mean 43 years 2 months) was matched to two typically developing comparison groups on i) chronological age and gender (CA; N=20; 35 - 63 years, mean 43 years 9 months), and ii) verbal mental age and gender (MA; N=20; 5 - 14 years, mean 9 years 8 months). Verbal MA was measured using the British Picture Vocabulary Scale (BPVS II; Dunn, Dunn, Whetton, & Burley, 1997); see Table 1 for group demographics. The adults with WS were recruited via the Williams Syndrome Foundation. Fifteen individuals with WS had previously had their clinical diagnosis confirmed with fluorescent in situ hybridization (FISH) testing to detect the deletion of one copy of the elastin gene on chromosome 7. The remaining five individuals had a clinical diagnosis, but this took place prior to the implementation of routine genetic testing. Three lived independently and seventeen lived at home with their parents / carers or in sheltered accommodation. Six were in some form of employment (supermarket and office workers / charity shop attendant / help in voluntary organisations) while the rest attended daycare centres or receive state-proved care assistance.

The participants in the two typical comparison groups received £6.00 for their participation. This study received positive ethical opinion from the local ethics committee prior to commencement.

INSERT TABLE 1 ABOUT HERE

Materials & Design

Forty-eight colour pictures from six semantic categories (animals, clothing, fruit, tools, toys, & vehicles) were taken from the Snodgrass and Vanderwart (1980) set, and matched for concept and frequency. Twenty-four images made up the stimuli for the shallow processing condition and twenty-four were selected for the deep processing stimuli. Each condition contained four exemplars of each of the six semantic categories and no item was duplicated across the conditions. In the shallow condition, half of the images were framed with a black border, and half were unframed (providing a perceptual level difference). A further twenty-four images (four from each semantic category), not included in the encoding stimuli set, were selected for the new items presented during the test phase.

The task was programmed using Eprime v2.00 (Psychology Software Tools, Inc.) and stimuli were presented on a Toshiba laptop with a twelve inch screen. A4 laminated examples of the stimuli (not included in the experimental stimuli set) were used as visual aids for all participants during explanation of the task. See Appendix 1 for a breakdown of item / category / condition allocation.

Procedure

Testing sessions for participants the WS took place in their homes, with a parent / carer present or nearby. Testing for the typical comparison groups took place in the Psychology Department at a local University. To commence the session, the participants were greeted by

the experimenter and seated in a comfortable chair in front of the computer. The experimenter outlined the experimental procedure, using the A4 laminate sheets to aid explanation, and invited each participant to read and sign an informed consent form. Where certain individuals from the WS group did not have sufficient reading ability, their parent / carer read the information sheet out loud. Written informed assent was provided by the adults with WS where possible and was always in addition to consent provided by the individual's parent / carer.

During the encoding phase, participants were presented with the forty-eight stimuli, one at a time on a computer screen. Each item was preceded with a '?' in Arial font size 28, displayed on screen for five seconds. During this time the experimenter asked an encoding question which was presented in either shallow or deep processing format. The shallow encoding question was always *'Is the next item in a frame?'* thus focussing on perceptual features of the item. The deep encoding questions always focussed on the item's semantic category membership e.g. *'Is the next item something a workman would use / a type of fruit / something you would play with?'* All questions required a verbal YES / NO response which was recorded manually by the experimenter. Half of the responses in each condition were 'YES' and half were 'NO'. Each item remained on screen for three seconds and was followed by a blank inter-stimulus interval of 250ms. The order of presentation was pseudo-randomised to ensure that no two images from the same semantic category were presented sequentially, irrespective of whether they were accompanied with shallow or deep encoding instructions. The first two and last two stimuli in the list acted as buffers and were not included in the test stimuli.

Immediately after the study phase, participants were presented with on-screen instructions advising they would be shown a further series of images one at a time and they were to identify whether they had seen each previously or not, by pressing designated YES / NO keys on the keyboard. The experimenter verbalised these instructions, and encouraged the participants to ask questions to ensure they participants understood the procedure during the test phase.

At test, participants were shown forty-eight images in randomised order one at a time on screen; twenty-four original items (four from each of the six semantic categories) and twenty-four new items. Twelve of the original items were selected from the deep encoding stimuli and the remaining twelve from the shallow encoding stimuli. The correct YES / NO responses during encoding were divided equally across the twenty-four stimuli. The participants had to identify if they had seen each image during the study phase by pressing designated YES / NO keys on the keyboard. Each image remained on screen for a maximum of five seconds. Participants were encouraged to respond as quickly as possible. If they did not respond within the 5-second time limit the next image was automatically displayed. Each image was interspersed with an inter-stimulus interval screen displaying a fixation cross for 250ms. All participants performed a 6-item practice session on the computer to ensure they understood the task instructions.

RESULTS

Correctly Identify Previous Studied Pictures (Hits)

Summary data are presented in Table 2. To compare differences in remembering previously seen pictures (hit rates) between the deep and shallow processing conditions, a 2 x 3 mixed

analysis of variance (ANOVA) was used, with LoP (deep, shallow) as the within-participants factor and Group (WS, CA, MA) as the between-participants factor. There was a significant main effect of group [$F(2,57) = 3.83, p < 0.05$] as the WS group performed significantly less accurately than the CA group ($p < 0.05$), but comparable to the MA group ($p > 0.05$). The CA group also performed significantly more accurately than the MA group showing a general increase in accuracy with age in typical development ($p < 0.05$).

There was a significant main effect of LoP [$F(1,57) = 87.624, p < 0.001$] demonstrating a successful task manipulation, with a lower hit rates for shallow processed pictures. Although the interaction between Group and LoP did not reach significance ($p = 0.09$) and suggests equivalent levels of semantic memory utilization, effects sizes were calculated to aid in the interpretation of the data. These data revealed a notably smaller effect size between the LoP conditions for the WS group ($d = 0.90; p < 0.01$) compared with both the CA ($d = 1.71; p < 0.001$) and MA typically developing groups ($d = 1.66; p < 0.001$). This pattern is also evident from Figure 1 and Table 2 where shallow processing hit rates were equivalent across groups (all $ps > 0.05$) and for deeper processed items WS hit rates were lower (WS vs CA $p < 0.01$; WS vs MA $p = 0.06$). Controlling for correctly rejecting new items (described below) did not affect the pattern of LoP between groups.

INSERT FIGURE 1 ABOUT HERE

A 2 x 3 ANOVA with the same factors was applied to the reaction time (RT) data. There was a significant main effect of group [$F(2,57) = 5.3, p < 0.01$] as the WS performed the task significantly slower than the CA group ($p < 0.05$) and with a trend towards being slower than the MA group ($p = 0.057$). There was no significant difference in RT between the two typical groups. There was a significant main effect of LoP [$F(1,57) = 18.24, p < 0.01$] demonstrating quicker identification of previously studied ‘*deep*’ pictures than ‘*shallow*’ items. The interaction between LoP and Group was not significant.

Correctly Rejecting Unstudied Pictures (Correct Rejections)

A one-way ANOVA was conducted to identify group differences in correctly rejecting the new items. There was a significant effect of Group [$F(2,59) = 8.931, p < 0.001$]. The WS group showed significantly more errors when identifying unseen items as new, compared to both the CA group ($p < 0.01$) and the MA group ($p < 0.01$), but there was no significant difference between the CA and MA groups (near ceiling performance).

There was also a significant difference between groups for RT to new items [$F(2,59) = 12.509, p < 0.001$]. The WS group were significantly slower than both the CA group ($p < 0.001$) and the MA group ($p < 0.01$). The difference in RT between the CA and MA groups did not reach significance.

INSERT TABLE 2 ABOUT HERE

DISCUSSION

The primary aim of the current study was to investigate whether adults with WS (aged 35+ years) could benefit from semantic support during episodic memory encoding and subsequent retrieval, thus showing greater accuracy when processing information at a ‘deeper’ level. Would the benefit of ‘deeper’ processing and semantic elaboration be equivalent in typical development and in WS? Using a levels of processing paradigm (LoP; Craik & Lockhart, 1972) it was anticipated that recognition of previously presented pictures would be overall more difficult (indexed by lower hits and increased RT) for individuals with WS. Alongside a generalised deficit in episodic memory we predicted that, like other populations with known hippocampal dysfunction (e.g. normal ageing, Grady & Craik, 2000; amnesia, Gardiner Brandt, Vargha-Khadem, Baddeley, & Mishkin, 2006) performance could be boosted by semantic support strategies, in this case ‘deep’, compared to ‘shallow’, processing.

Consider first the overall recognition performance of the participants with WS compared to chronically- and mental aged-matched typically developing participants. Successfully remembering previously studied pictures was relatively impaired in WS compared to the chronologically age matched typically developing participants, but not the mental age matched typically developing group. It is not surprising that individuals with WS do not perform at the level of their chronological age due to the presence of intellectual difficulties (evidenced here by lower verbal mental age than chronological age). Indeed the WS adults were able to encode and subsequently remember episodic information at a level expected by their mental age capacity. It could be claimed that this group do show a deficit of episodic memory per se but that deficit is entwined with their general level of intellectual functioning, here shown by their verbal mental age. However, increased response times during the

recognition of previously studied items (as a measure of the efficiency of episodic remembering) provide the tentative suggestion that individuals with WS may have impaired search processes through long-term memory (less efficient than typical) and that the adults with WS were impaired compared to both CA and MA typical control groups. Reaction times atypicalities (even in relation to mental age) and fewer hit rates may be suggestive of a specific episodic memory deficit in this group of adults with WS.

The episodic memory performance of the WS group was relatively impaired in the current study even though an arguably less demanding episodic recognition memory task was employed. Indeed, in the 'normal' ageing literature the magnitude of episodic memory deficits ranges between tasks that have little environmental support to bind individual attributes of an event (e.g. cued and free recall) compared to a great deal of environmental support which is present when the material is represented in the test phase (recognition; Naveh-Benjamin, 2000). Therefore, episodic remembering using an 'easy' picture recognition paradigm employed here shows performance at a mental age level (in terms of hit rates). Interestingly, research investigating age effects on associative and episodic memory have found that when semantic memory is heavily involved during the retrieval of previously studied items age differences tend to disappear. For instance, when recalling semantically related pairs in a paired associate episodic memory task or retrieving over-learned (but demanding) information age differences are removed or minimised (see for example Riby, Perfect, & Stollery, 2004). The pattern of data in the normal ageing literature leads on to the primary aim of the current experiment; namely, does semantic memory support domains of cognition impairment in WS?

Given the finding of the link between episodic memory and everyday memory capabilities and the reported success of interventions aimed at promoting semantic elaboration strategies in impaired populations our main finding is notable (see for instance Bellezza, 1981). Craik and Lockhart (1972) provide us with a paradigm ideally suited to examine how both components of declarative memory interact to support memory performance. Under normal conditions, WS individuals find problematic the encoding of new information into memory and may adopt inefficient strategies while forming a new memory trace. In present study, by encouraging participants to create a rich representation in memory by assessing whether the study item is part of a category, this aids performance compared to a shallow encoding strategy. For example, making the decision that a 'hammer' is a type of 'tool' drives elaborative processes, thus creating a rich, coherent and multi-faceted memory representation. The results of the study also upheld the second hypothesis; the WS group significantly benefited from a semantic encoding strategy reported in typically developing younger and older adults during LoP tasks (Luo, Hendricks, & Craik, 2007; Troyer, Häfliger, Cadieux, & Craik, 2006). One caveat is that after inspection of the effect sizes between the deep and shallow hit rates it is clear that there was a very large effect in both the CA and the MA groups. In contrast, the effect size reported for the WS group, whilst still large, was notably smaller than the two comparison groups due to the numerically lower hit rate and greater variability / heterogeneity of performance in the deep condition. Further work is clearly warranted examining in more detail semantic strategies employed by WS participants during an episodic memory learning experience. The practical implication would be the refinement of formal training to optimize encoding which can benefit the everyday memory of these individuals.

We also considered correct rejections and false alarms to new unstudied items as a marker of impaired memory processes. Although not a primary concern here, such measures have been useful in examining controlled processing and monitoring mechanisms involved in episodic memory (e.g. Gallo, 2004) and may contribute to the work that already exists on executive-frontal lobe function in WS (Greer et al. 2013; Rhodes Riby, Park, Fraser, & Campbell, 2010). Indeed, it should be noted that there is a family of processing mechanisms involved in episodic memory retrieval including an assessment of the familiarity of the test item, recollection which is considered episodic memory proper where rich details of the previous encoding episodic are retrieved, and post retrieval monitoring processes that are engaged when there is uncertainty when making a judgement regarding the status of a test item (Yonelinas, 2002). Here, there was a significantly larger false alarm error rates reported by the WS when rejecting new items, compared with the CA and MA groups. This pattern was accompanied by an increased evaluation time when correctly rejecting new items in the WS group. Being more disposed to false memories suggests that the recognition paradigm employed here did not produce a situation where the new items were distinctive enough to reject as an unstudied item. An increase in errors and response time to correct rejection in WS suggests uncertainty identifying an unstudied item and even after more consideration and monitoring of responses more false memories occur for the WS participants. Elsewhere, in the spatial domain poor error monitoring has been seen to be a key characteristic of the WS profile (Smith et al., 2009; Rhodes et al., 2010).

From our interpretation of the data, we suggest that the relationship between episodic and semantic components of the declarative system in WS is relatively proficient. Our data are not consistent with the alternative interpretation that general learning difficulties result in

problems with how episodic and semantic operations interact to aid memory performance. In an earlier study carried out on the developmental disorder, autism, Toichi and Kamio (2002) found participants were unable to capitalise on depths of processing and performance was in fact superior in the shallow condition. So, when compared to non-verbal typically developing matches, participants with autism favoured a rote perceptual strategy at encoding to aid subsequent memory performance. To conclude, we have demonstrated that, under conditions of recognition, adults with WS aged 35+ years present a LoP bias with greater recognition of deeply encoded items than those encoded with shallow encoding. Although this contradicts previous research on autism, it is in line with other populations such as amnesia and normal ageing where although memory ability may be impaired employing appropriate encoding strategies minimises deficits. Our consideration of correct rejections although not a primary concern in the present study provides the groundwork for future studies that not only considers elaborative semantic support strategies at encoding but also controlled monitoring processes at retrieval since such executive processes are impaired and contribute to the increased false memories observed here.

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Figure1

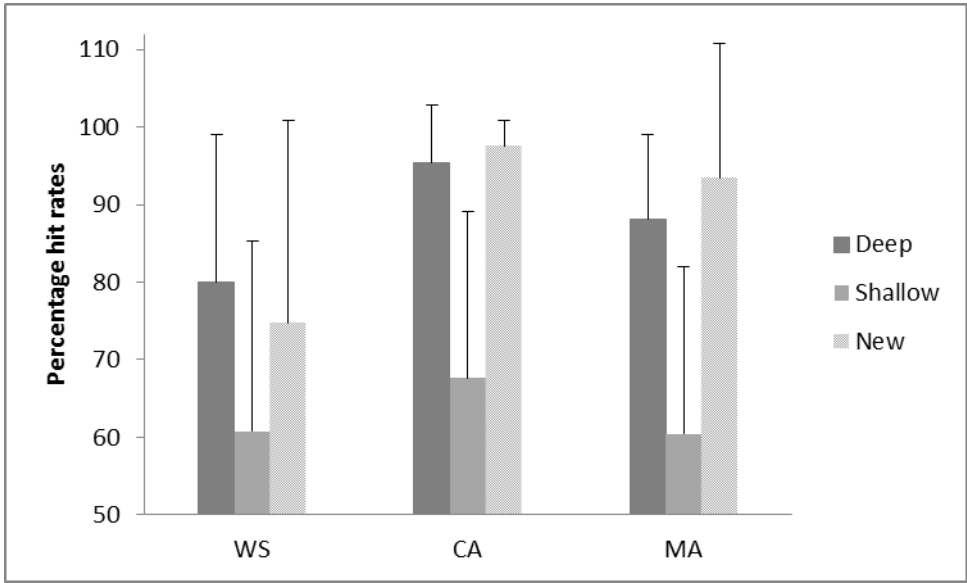


Figure 1: Mean hit rates recorded by the WS, CA, and MA groups for deep and shallow encoding, and for new items

Table 1: Demographic information for the WS, CA, and MA groups

	WS	CA	MA
n	20	20	20
Age range	35 – 63 yrs	35 – 63 yrs	5 – 14 yrs
Mean age (<i>SD</i>)	43:2 (6:7)	43:9 (6:6)	9:8 (2:4)
Mean BPVS score (<i>SD</i>)	105.00 (17.37)	n/a	105.40 (18.29)
Vocabulary age	10:9 (3:7)	n/a	11:04 (2:7)

Years:months; standard deviations (*SD*) in parentheses

Table 2: Hit rates and RT in ms in deep and shallow encoding conditions, and new items, for the WS, CA, and MA groups (*standard deviations in parentheses*)

	WS	CA	MA
n	20	20	20
Deep Hits %	80.05 (18.98)	95.45 (7.42)	88.05 (10.97)
Shallow Hits %	60.80 (24.53)	67.65 (21.49)	52.82 (21.49)
New Hits %	74.75 (26.15)	97.60 (3.28)	93.45 (17.35)
Deep RT ms	1544.26 (649.19)	979.75 (320.27)	1210.20 (502.26)
Shallow RT ms	1619.78 (664.44)	1180.25 (352.40)	1350.63 (444.56)
New RT ms	1641.09 (584.45)	990.11 (248.97)	1159.30 (379.03)