Abstract

Introduction
Autism is a neurodevelopmental disorder characterised by a change in connectivity between different brain regions resulting in behavioural changes and, to an extent, memory deficits. This review presents a summary of the first studies (mostly our own) exploring metamemory in autism. Metamemory concerns how proficiently people can monitor and control their memory system. Does a metamemory deficit contribute to the memory deficit observed in autism?

Conclusion
We report that most studies suggest people with high-functioning autism or Asperger syndrome can estimate accurately their memory performance, and can also use these evaluations to adapt their memory strategy. This is an important finding in terms of the education of people with autism; proficient metamemory is thought to be critical for academic achievement.

Introduction
Autism is a neurodevelopmental disorder that primarily affects social interaction and communication. The ‘developmental disconnection model’ links the symptoms of autism spectrum disorder (ASD) to weak functional connectivity in the brain. Neuroimaging suggests that, for example, deficient self-reflective thought processes (e.g. Theory of Mind (ToM)) are directly linked to brain abnormalities. A growing literature has also identified memory impairment in autism, with several studies suggesting that the memory profile observed in ASD is linked to abnormalities of the hippocampal formation and other neural regions including the amygdala and the frontal cortex, areas thought to be responsible for strategic regulation of memory.

Relative to other areas of cognition, studies examining how people with ASD retrieve information from memory are still in their infancy (for a review, see). Research has shown that people with ASD (including mostly high-functioning autism or Asperger syndrome) present with an impairment in the capacity to learn new information (e.g. new word pair associations). Source memory (the ability to retrieve contextual information about the circumstances of acquiring new information) is also less efficient in ASD but see). Furthermore, several studies have now demonstrated that the quality of autobiographical memories (memories for personal information and events from one’s own life) retrieved by people with ASD is poorer in comparison to controls.

What might cause and contribute to this memory deficit? A recent development in the ASD literature consists of exploring what people know about their memory processes and performance rather than what they retrieve from memory. Awareness of one’s own memory was first described in the Developmental Psychology literature by Flavell under the term metamemory. Metamemory concerns beliefs, attitudes, sensations and knowledge about memory. According to a framework proposed by Nelson and Narens, metamemory entails the processes by which people reflect upon or estimate their memory performance (monitoring) and the use of this knowledge to control their learning (control) (see Figure 1). This model suggests that

Figure 1: Metamemory model and summary of findings in ASD.
the proficient regulation of memory processes is necessary to maintain adequate memory performance. As a result, the investigation of metamemory in children has been motivated by the assumption that the development of appropriate metamemory skills leads to higher academic performance.4 Despite its educational implications, metamemory remains underexplored in ASD. The novelty of this review is to present a summary of the first studies exploring metamemory processes in ASD. The goal of this research is to investigate whether a metamemory deficit might contribute to the memory deficit in ASD. If people with ASD cannot monitor and control their cognitive system there will be consequences for their memory function.

Metamemory monitoring in ASD

Measures of monitoring vary according to the type of memory task (learning new information or retrieving general knowledge) and according to when the judgements are made (at the learning phase, the retrieval phase or even after the retrieval phase) (see Figure 1). The very first studies in ASD tended to use Judgements-of-Confidence (JOCs), which consist of asking participants to estimate the correctness of their answer after they have produced it.7 The literature using this paradigm in children with ASD has produced equivocal results. For example, Wilkinson et al.18 investigated JOC accuracy in children with ASD using a face recognition task—an area impaired in autism.19,20 After studying 24 face photographs, participants carried out a recognition test in which they were presented with 48 photographs and had to detect the faces presented earlier amongst an equal set of foils. Children gave JOCs by reporting whether they were ‘certain’, ‘somewhat certain’ or ‘guessing’ after having given their answers. Memory performance did not vary with the levels of certainty in the ASD group; children with autism could not discriminate between correct and incorrect responses in their confidence. However, Wojcik et al.21 showed that children and adolescents with ASD gave JOCs which were as accurate as controls when they were asked to estimate their accuracy in recalling school-like instructions (e.g. Pick up the red ruler and put it in the yellow box, then touch the blue pencil). Thus, studies exploring accuracy of JOCs revealed contradictory findings.

To explore monitoring operations linked to the retrieval of information, Wojcik et al.22 used the Feeling-of-knowing (FOK) paradigm. FOKs are predictions about likelihood of future recognition of items, which are presently non-recalled23 and can be assessed for both semantic (memory for facts) and episodic memory (memory for recent events). Participants predict the likelihood that they will identify the correct information when presented amongst some choices. The focus is on whether or not the judgements distinguish between what is and what is not remembered or known.

In healthy populations, even very young children have accurate FOKs (4–5 years).23,24,25 Wojcik et al.22 ran two parallel experiments on episodic and semantic FOK. In the episodic task, participants were presented with 20 cue–target pairs (e.g. forest–CAPITAL) and when presented with the cue they were asked to recall the corresponding item. When participants could not recall the corresponding item, they were asked to make a FOK prediction by saying whether or not they would be able to recognise the item amongst other words. To explore semantic FOK, children had to verbally define words from the Peabody Picture Vocabulary Test.24 On words they could not define, they had to make FOK judgements23,25.

However, our results showed that children with ASD were inaccurate at predicting their performance using the FOK paradigm—but only on the episodic task. Children with ASD thus do not appear to suffer from a generalised metamemory deficit when asked to predict their future performance at retrieval. In fact, the deficit observed seems to strongly depend on the material presented (new information to learn versus general knowledge information already known).

In a more recent study, Wojcik et al.26 explored metamemory during encoding using Judgements-of-Learning (JOLs). In a typical JOL procedure, participants are presented with word pairs (a cue word and a target word) and asked to make a prediction of the likelihood that they will recall the target word when presented with the cue word. These judgements can be made either immediately after the presentation of each item (immediate JOLs) or after a delay (delayed JOLs). Both healthy children27,28 and adults29 show an advantage of delayed over immediate JOLs (the delayed JOL effect). According to Nelson and Dunlosky, this effect occurs because the delayed JOL is based on information from long-term memory (LTM), which in fact resembles the information retrieved from LTM when searching for the target word. Immediate JOLs, on the other hand, are more likely to be based on information issued from short-term memory which has a limited validity in predicting future recall from LTM. The delayed JOL effect demonstrates, therefore, that JOLs are affected by the type of information retrieved from memory at the time of judgement.

Wojcik et al.26 presented children with ASD with 24 word pairs (e.g. dog–CAR) and asked for children’s immediate JOLs. In a separate task, a further 24 pairs were used for a delayed JOLs task. For the immediate JOL, after studying each pair they were re-presented with the cue word...
and asked to make a JOL by predicting whether in about five minutes they would be able to recall the target word when shown the cue word. In the delayed condition, JOLs were made after the study of all items. The results showed for the first time in the literature that children with ASD could accurately predict their later recall and also that like typically developing children they could switch to more appropriate mnemonic cues resulting in a delayed JOL effect.

In summary, the experimental studies in autism have used paradigms where participants are asked to either predict their future memory performance during encoding at retrieval or after retrieval (see Table 1). The studies mainly revealed that children with ASD can correctly estimate their memory function; monitoring was, for the most part, intact.

**Metamemory control in ASD**

Metamemory control refers to the ability to regulate memory strategy. In autism, there are impairments in strategic learning. For example, many studies indicate that people with ASD do not spontaneously use the characteristics of the material to support their encoding of the stimuli presented. Metamemory control is often measured by whether people allocate appropriate or sufficient time to the processing of to-be-learned materials.

According to the metamemory framework (see Figure 1), strategic deficits, including the ones observed in ASD, could be the consequence of a breakdown of the monitoring-control relationship. Through effective monitoring, learners control their cognitive resources to achieve an optimum level of performance; even first graders use JOLs to regulate study time and that more study time is attributed to items previously given lower JOLs so perceived as less well learned. Perhaps, even though monitoring is intact in ASD, there is nonetheless a failure to regulate memory properly.

In the above JOL article, Wojcik et al. (in press) also assessed whether or not children with ASD could use their metacognitive judgements to regulate their strategy and, in particular, their study time. Children had to study 15 difficult (abstract: dream–FLOWER) and 15 easy (concrete: house–FLOWER) word pairs and predict their future recall of the second item of the pair giving a JOL. Then all participants were presented with the same word pairs again to study and were given the opportunity to spend as long as they wanted studying the items. The findings clearly showed that JOLs given by adolescents with ASD varied according to word difficulty, with higher JOLs given to easier words (see Figure 2). Furthermore, the results showed that adolescents with ASD not only allocated the same amount of study time as controls but also that study time allocation was related to their JOLs (more time given to study items that were given lower JOLs).

In summary, these findings suggest that children with ASD can regulate their memory strategies (at least study time) according to their estimation of memory performance, suggesting that children with ASD can regulate their learning. It may be the case that children with ASD have difficulties initiating memory strategies in general, but that asking them to estimate their memory performance (JOL) helps with the initiation of the correct memory strategy (as we found with study time in our experiment).

**Discussion**

The authors have referenced some of their own studies in this review. These referenced studies have been.

---

**Table 1 Metamemory judgements in ASD**

| Metamemory judgement | Memory phase | Material type           | Findings in ASD   | References               |
|----------------------|--------------|-------------------------|-------------------|--------------------------|
| JOL                  | Encoding     | Word pairs              | Preserved         | Wojcik et al. (in press) |
| FOK                  | Retrieval    | Word pairs General knowledge | Impaired Preserved | Wojcik et al. (2012)22, Wojcik et al. (2012) |
| JOC                  | Retrieval    | Instructions Faces      | Preserved Impaired | Wilkinson et al. (2010)18, Wojcik et al. (2011)21 |

FOK, Feeling-of-knowing; JOC, Judgement-of-confidence; JOL, Judgement-of-learning.

---

**Figure 2:** Mean study time in seconds for easy and difficult words to learn showing that both typically developed children and children with ASD spend more time studying difficult than easy words.
conducted in accordance with the Declaration of Helsinki (1964) and the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

This review summarises recent studies exploring an important question: whether or not children and adolescents with ASD are aware of their memory functioning. The conclusion is a rather positive one, as most of the studies suggest that in fact people with high-functioning autism or Asperger syndrome can not only estimate accurately their memory performance but these judgements are also related to the appropriate allocation of study time. Furthermore, children with ASD appear to have knowledge of their memory functioning; they can predict the impact of several different factors on their performance such as task difficulty. This is a critical finding in terms of education, especially as metacognition is known to have an impact on academic achievement.

These findings seem surprising in regards to the cognitive and behavioural deficits often observed in autism. Many studies have demonstrated that people with autism show impaired social cognition and have difficulties with tasks assessing ToM. ToM research assesses children’s understanding of others’ mental states, of their own mental states and the ability to self-reflect. In many regards, metamemory and ToM appear to share a common theme or a common process. Lock and Schneider indeed showed that ToM predicted later metamemory performance in typically developing children, thus suggesting a clear link between these concepts. In the same vein, Williams argued that people with autism find it difficult to think about their own mind. One would thus predict that metamemory should be impaired in children showing ToM difficulties and thus in children with autism. In other words, the frequently observed impaired acquisition of concepts of self and other in autism could be related to a deficit in reflection, leading to impaired metamemory.

Here we would like to offer an alternative explanation to support what seems to be dissociation between preserved metamemory and impaired ToM in ASD. That is, metamemory as assessed by the studies presented above does not require self-related processes in the same way as ToM tasks do. Predicting future memory performance on word pairs such as DOG–CAR probably involves less self-reflective processes than having to put oneself in someone else’s shoes to predict their behaviour.

On the other hand, where metamemory deficits have been found (episodic FOX; JOC) we propose a memory-based explanation. Recent theories suggest that our ability to predict or estimate our memory performance, in fact, relies on the quality of our memory processes. If these memory processes are deficient, people will not be able to predict their memory performance. Another way to explain this might be the fact that different metacognitive judgements are based on different types of information in consciousness. Any metamemory difficulties in autism would thus depend not only on the type of memory task, but also on the type of judgement made. We would like to suggest that people with ASD can accurately estimate their memory performance using objective and perceptual information/cues but that they might fail to monitor their memory system when it requires more subjectivity, i.e. is related to the self and perspective taking (e.g. the self in the past and the self in the future). Empirical work examining this idea is a priority.

**Conclusion**

To conclude, this critical review shows that, overall, children and adolescents with ASD have a relatively efficient metacognitive system and can estimate their memory performance and regulate their memory strategies adequately. Knowing that at least some metacognitive competences are preserved in this population could potentially guide educators in choosing the most appropriate teaching methods. Future research should explore whether individual with ASD are also aware of their competences in other domains and in particular, the social domain.

**Acknowledgement**

We would like to thank Dr. Chris Moulin for his comments on this manuscript.

**References**

1. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders (Fourth Edition) (DSM–IV). Washington, DC: APA; 1994.
2. Belmonte MK, Cook EH Jr, Anderson GM, Rubenstein JL, Greenough WT, Beckel-Mitchener A, et al. Autism as a disorder of neural information processing: directions for research and targets for therapy. Mol Psychiatry. 2004 Jul;9(7):646–63.
3. Boucher J, Mayes A, Cowell P, Broks P, Farrant A, Roberts NA, et al. A combined clinical, neuropsychological and neuroanatomical study of adults with high functioning autism. Cogn Neuropsychiatry. 2005 Jun;10(3):165–213.
4. Salmon CH, de Haan M, Friston KJ, Gadian DG, Vargha-Khadem F. Investigating individual differences in brain abnormalities in autism. Philos Trans R Soc Lond B Biol Sci. 2003 Feb;358(1430):405–13.
5. Boucher J, Mayes A, Bigham S. Memory in autistic spectrum disorder. Psychol Bull. 2012 May;138(8):458–96.
6. Williams DL, Goldstein G, Minshew NJ. Neuropsychologic functioning in children with autism: further evidence for disordered complex information-processing. Child Neuropsychol. 2006 Aug;12(4-5):279–98.
7. Hala S, Rasmussen C, Henderson AM. Three types of source monitoring by children with and without autism: the role of executive function. J Autism Dev Disord. 2005 Feb;35(1):75–89.
8. Lind SE, Bowler DM. Recognition memory, self-other source memory, and
theory-of-mind in children with autism spectrum disorder. J Autism Dev Disord. 2009 Sep;39(9):1231–9.
9. Bowler DM, Gardiner JM, Berthollier N. Source memory in adolescents and adults with Asperger's syndrome. J Autism Dev Disord. 2004 Oct;34(5):533–42.
10. Russell J, Jarrold C. Memory for actions in children with autism: self versus other. Cogn Neuropsychiatry. 1999 Nov;4(4):303–31.
11. Souchay C, Wojcik DZ, Williams HL, Craithen S, Clarke P. Recollection in adolescents with Autism Spectrum Disorder. Cortex. 2013 Jun;49(6):1596–609.
12. Bruck M, London K, Landa R, Goodman J. Autobiographical memory and suggestibility in children with ASD. Dev Psychopathol. 2007 Winter;19(1):73–95.
13. Tanweer T, Rathbone CJ, Souchay C. Autobiographical memory, autonoetic consciousness, and identity in Asperger syndrome. Neuropsychologia. 2010 Mar;48(4):900–8.
14. Flavell J. First discussant's comments: what is memory development the development of? Human Dev. 1971;1:324–40.
15. Nelson TO, Naren L. Metamemory: a theoretical framework and new findings. In: Bower G, editor. The psychology of learning and motivation, advances in research and theory. San Diego, CA: Academic Press; 2012. p125–173.
16. Schneider W. The development of metamnemonic knowledge in children and adolescents: major trends and implications for education. Int Mind Brain Educ. 2008;2(3):114–21.
17. Koriat A, Ben-Zur H, Druch A. The contextualization of memory for input and output events. Psychol Res. 1991;53:260–70.
18. Wilkinson DA, Best CA, Minshew NJ, Strauss MS. Memory awareness for faces in individuals with autism. J Autism Dev Disord. 2010 Nov;40(11):1371–7.
19. Rouse H, Donnelly N, Hadwin JA, Moulin CJA, Souchay C. Metacognitive Judgments-of-Learning in adolescents with Autism Spectrum Disorder. Autism. Forthcoming.
20. Schneider W, Vise M, Lockl K, Nelson TO. Developmental trends in children’s memory monitoring: evidence from a judgment-of-learning task. Cogn Dev. 2000;15:115–34.
21. Koriat A, Shitzer-Reichert R. Metacognitive judgments and their accuracy: insights from the processes underlying judgments of learning in children. In: Chambers P, Izateau M, Marescaux PJ, editors. Metacognition: process, function, and use. New York, NY: Kluwer; 2002. p1–17.
22. Nelson TO, Dunlosky J. When people’s judgments of learning (JOLs) are extremely accurate at predicting subsequent recall: the “delayed-JOL effect.” Psychol Sci. 1991;2:267–70.
23. Nelson TO, Dunlosky J. How shall we explain the delayed-judgment of-learning effect? Psychol Sci. 1992;3:317–8.
24. Lockl K, Schneider W. Knowledge about the mind: links between theory of mind and later metamemory. Child Dev. 2007 Jan;78(1):148–67.
25. Lockl K, Schneider W. Metakognition in children and adolescents with autism spectrum disorder. OA Autism 2013 May 01;1(2):12.