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Metacognitive judgments-of-learning in adolescents with autism spectrum disorder

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Abstract

This study investigated metacognitive monitoring abilities in adolescents with autism spectrum disorder in two experiments using the judgment-of-learning paradigm. Participants were asked to predict their future recall of unrelated word pairs during the learning phase. Experiment 1 compared judgments-of-learning made immediately after learning and judgments-of-learning made after a delay. We found that both groups overestimated their memory performance but that overall there were no group differences in judgment-of-learning accuracy. Additionally, both groups displayed the standard delayed judgment-of-learning effect (yielding greater judgment accuracy in delayed compared to immediate judgments), suggesting that both groups were able to use appropriate information in making their judgments-of-learning. Experiment 2 assessed whether adolescents with autism spectrum disorder could regulate their study time according to their judgments-of-learning using a self-paced learning procedure. Results showed that both groups spent more time learning items given lower judgments-of-learning. Finally, Experiment 2 showed that judgments-of-learning and study time varied according to item difficulty in both groups. As a whole, these findings demonstrate that adolescents with autism spectrum disorder can accurately gauge their memory performance while learning new word associations and use these skills to control their study time at learning.

Keywords

autism, judgment-of-learning, memory, metamemory

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder primarily affecting social and communication functioning. Recent studies show that ASD is also characterized by memory impairment (see Boucher et al., 2012). The novelty of this study is not to look at memory performance but to understand awareness of memory performance in adolescents with autism.

Awareness of memory performance was first described under the term *metamemory*, originally proposed by Flavell (1971). Metamemory encapsulates beliefs, sensations and knowledge about memory function (e.g. Flavell, 1979), including knowledge of factors affecting memory performance, the memory abilities of others and the effect of memory strategies (e.g. Flavell, 1979; Flavell et al., 1993). Whether or not people are aware of their memory performance has critical and direct implications. The key issue is that awareness of memory operations during learning will guide appropriate and strategic allocation of cognitive resources during learning. For example, several studies have shown that predicting how well a word has been learnt will influence the time spent studying this word when presented again (Nelson and Leonesio, 1988). In autism, recent evidence suggests difficulties in implementing and regulating memory strategies (Bowler et al., 2008; Gaigg et al., 2008; Smith et al., 2007). This could be potentially caused by a metamemory failure and, in particular, difficulties in estimating memory performance, for example, how well items have been learnt and will be recalled. However, very few studies have investigated metamemory in autism. The novelty of this study is to empirically ascertain whether or not adolescents with autism can monitor and thus predict their future memory performance while learning new

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information (word pairs) and also whether they can use this information to regulate their memory strategies (study time).

Several frameworks and in particular the Theory of Mind (ToM) framework in ASD predict that metamemory functioning might be impaired in ASD. Metamemory and ToM research share a common theme: children's knowledge about mental phenomena. While ToM research assesses children's understanding of mental states, metacognition – and in particular metamemory – explores children's understanding of their own memory functioning. In fact, several researchers suggest that in being higher-order judgments of understanding, ToM could be considered metacognitive (Baron-Cohen, 1989; Flavell, 2000; Kuhn, 2000). Recently, Lockl and Schneider (2007) showed that ToM predicted later metamemory performance in typically developing (TD) children, thus suggesting a clear link between these concepts. Lockl and Schneider (2007) also suggest that the acquisition of the concept of representation captured in ToM tasks is essential for the development of metacognition – metacognitive knowledge can only be acquired by reflecting on one's own and others' memory function. Research in autism typically shows that ASD children have impaired ToM and have difficulties in attributing mental states to others (e.g. Baron-Cohen et al., 1985). Furthermore, Williams (2010) argued that individuals with autism have difficulties thinking about their own mind. In the memory literature, a recent study showed that low retrieval of autobiographical memories in adolescents and adults with ASD was closely related to ToM impairments (Adler et al., 2010). These findings are consistent with the theory developed by Powell and Jordan (1993) according to which memory impairments in autism are due to a lack of 'Experiencing self'. Individuals with ASD are able to encode events at an objective and perceptual level, but not in a subjective manner. Thus, the frequently observed impaired acquisition of concepts of self and other in autism (Hobson, 1993; Jordan and Powell, 1995) could be related to a deficit in reflection, leading to impaired metamemory.

However, despite this prediction, studies exploring metamemory in ASD are scarce and tend to show that individuals with ASD have unimpaired knowledge of their memory functioning. For example, Farrant et al. (1999b) in five experiments focused on knowledge about memory functioning in children with ASD (knowledge of factors affecting task performance, the abilities of others and the effect of memory strategies; Flavell, 1979). For example, Experiment 1 showed that children with ASD could accurately predict the effect of task difficulty on memory performance. Children were given a span task with two sets of pictures, an 'easy one' and a 'hard one' expected to be beyond the children's span. There were five pairs of cards, and the number of pictures on each pair were 13 and 4, 9 and 3, 10 and 3, 12 and 4 and 8 and 3. Children were asked to state which set of pictures they would like to choose. Results showed that children with ASD, like control participants, chose the 'easy sets', thus showing awareness of the impact of task difficulty on their performance. Similarly, we have also shown that children and adolescents with autism can predict the impact of learning conditions and, in particular, the enactment effect (better memory performance when words are acted compared to when the words are read) on their memory performance (Wojcik et al., 2011). In this study, children and adolescents with ASD were presented with school-like instructions to remember (*Pick up the red ruler and put it in the yellow box, then touch the blue pencil*) and at encoding, either were read the instructions by the experimenter or had to act the instructions. All children were also asked to estimate how well they had recalled the instructions. All children predict recalling more instructions when they acted the instructions out at encoding, thus acknowledging the fact that acting out the instructions would increase their memory performance. Farrant et al. (1999b) explored knowledge regarding memory strategies by giving children a questionnaire (similar to the one carried out by Kreutzer et al., 1975) to assess their knowledge about memory strategies. Results showed that children with ASD had good knowledge of memory strategies. These findings thus show that people with ASD predict the effect of different factors on their memory performance but also know which memory strategy to use depending on the task. These findings suggest that individuals with ASD acquire good knowledge about memory functioning (memory strategies for example) throughout childhood. However, what is less clear is whether or not individuals with autism are able to reflect and predict their own memory performance while learning new information. In other words, can individuals with ASD accurately judge their learning and predict their future memory performance?

To answer these questions, the experimental memory research and, in particular, the metamemory framework proposed by Nelson and Narens (1990) offer a wide range of measures assessing awareness of ongoing mental activities. This model describes two metamemory processes: *monitoring*, the awareness of items in memory and one's own memory performance (such as estimating how well an item has been learnt), and *control*, the manipulation of processes (such as memory strategies) that affect memory. The experimental literature exploring metamemory monitoring in children and adolescents has mainly used paradigms in which participants are asked to predict their future memory performance while retrieving the information such as the feeling-of-knowing (FOK) paradigm (Hart, 1965) or while learning the information as with the judgment-of-learning (JOL) paradigm (Arbuckle and Cuddy, 1969). So far, studies in ASD have only used judgments-of-confidence (JOC), which involves asking participants to estimate the accuracy of their answers after the recall or the recognition phase. In other words, children are asked to report how confident they are in the correctness of their answer, having already produced it. The literature using this paradigm in children with ASD reveals mixed findings. For example, Wilkinson et al. (2010) explored JOC accuracy in children with ASD using a face recognition task. Participants were presented, during the memory test, with 48 colour photographs of adult female faces, 24 old (previously seen at encoding) and 24 new. Following their answer, all participants were then asked to say how confident they felt regarding their answer. Results showed that children with ASD gave less accurate judgments, thus suggesting impaired awareness. On the contrary, our recent findings (Wojcik et al., 2011) showed that children and adolescents with ASD make as accurate confidence judgments as controls when asked to estimate their accuracy in recalling school-like instructions (*Pick up the red ruler and put it in the yellow box, then touch the blue pencil*). To the best of our knowledge, no study has yet explored whether or not children with ASD can accurately estimate their memory performance while learning. The novelty of this study is thus, for the first time in the literature, to explore monitoring processes at encoding, that is, while participants are learning the material. To do this, in two experiments, we assessed whether adolescents with ASD could accurately predict their memory performance using the JOL paradigm.

JOLs are predictions about future test performance on recently studied items and are thus predictions of future memory performance. In a typical procedure, participants are presented with word pairs (a cue word and a target word) and asked to make a JOL reflecting the likelihood that they will later recall the target word when presented with the cue word. These judgments can be made either immediately after the presentation of each item (immediate JOLs) or after a delay (delayed JOLs). JOLs are thus judgments usually made on paired word associate learning (PAL). In ASD, several studies have used PAL to assess memory performance. Interestingly, performance was unimpaired either when recall occurred immediately (Ambery et al., 2006; Minshew and Goldstein, 2001; Williams et al., 2006) or after a delay (Ambery et al., 2006; Gardiner et al., 2003; Minshew and Goldstein, 2001; Williams et al., 2006). In the ongoing studies, adolescents with ASD were thus assessed on a memory task not deficient in ASD. As a result, the strength of the present studies was to focus on JOLs in ASD rather than on memory performance. Developmental studies using JOLs suggest that first to fourth graders can accurately predict their future recall (e.g. Koriat and Shitzer-Reichert, 2002; Schneider et al., 2000). No study has yet explored JOLs in individuals with autism. However, accuracy of metacognitive judgments such as JOLs is a crucial issue as many studies showed that participants' predictions about how likely they are to remember an item are used to control further study. For example, when learners are allowed to control their study time at encoding, several studies showed that they generally allocate more time to items associated with lower JOL ratings (Nelson and Leonesio, 1988). As a result, understanding metacognitive accuracy in autism is critical as it might help to understand memory strategies impairments observed in this population. In Experiment 1, we will thus assess whether or not adolescents with ASD can accurately predict their memory performance at encoding using the JOL paradigm. In Experiment 2, we will examine whether or not adolescents with ASD can use their monitoring processes (JOLs) to regulate their learning strategies (study time).

General method

The experiments presented below involved adolescents with ASD recruited through parent support groups and educational organizations based in West Yorkshire, UK. The ASD and comparison participants were group-matched on age and IQ (as measured by the Wechsler Abbreviated Scale of Intelligence (WASI); Wechsler, 1999). The comparison children were recruited from mainstream schools in the Leeds area. They were included on the basis of matching the age of the participants with ASD participants. A large verbal IQ–performance IQ (VIQ-PIQ) was observed in the TD comparison group. However, it is important to note that all comparison children were excluded if they had a family history with first-degree relatives with major psychiatric disorders and/or ASD or any brain pathology. Furthermore, poor school attendance or evidence of low school achievement was also an exclusion criterion.

Adolescents with ASD all received formal diagnosis by a paediatrician, clinical psychologist and/or child psychiatrist. In the group of adolescents with ASD, 15 were diagnosed with Asperger's Syndrome (AS) and 6 with high-functioning autism (HFA). No significant differences (Mann–Whitney) were observed between these groups on any of the experimental tasks in Experiment 1 and Experiment 2 (analysis not reported here). All the adolescents with ASD were tested using the Autism Diagnostic Observation Schedule (ADOS, module 3 or 4; Lord et al., 2000) administered by a fully trained member of the research team. The total communication and social interaction score indicated that all children met the diagnostic criteria ($m = 10.33$, standard deviation (SD) = 2.41, range = 7–15, where the cut-off point for autism spectrum is 7 points, and for autism, it is 10 points). The scores for communication ($m = 3.62$, SD = 1.24, range = 1–6) and social interaction ($m = 6.67$, SD = 1.62, range = 4–10) were also taken into account.

Informed consent, according to the Declaration of Helsinki (BMJ, 1991), was obtained from the parents of all participants in accordance with procedures approved by the Institute of Psychological Sciences (University of Leeds, UK). Furthermore, verbal consent was obtained from all the participants.

Table 1. Descriptive statistics for the autism spectrum disorder (ASD) and comparison groups: Experiments 1 and 2.

	Experiment 1		Experiment 2	
	ASD	Comparison	ASD	Comparison
n	21	21	19	19
Age				
M	12.77	11.64	13.57	12.37
SD	2.34	2.49	2.46	2.56
Range	9.08–17.06	8.10–17.07	10.08–18.04	9.09–18.05
FIQ				
M	112.19	116.67	113.95	117.74
SD	13.83	13.27	12.80	13.38
VIQ				
M	113.62	122.29	115.11	124.11
SD	16.44	13.13	16.47	12.37
PIQ				
M	107.09	107.01	108.63	107.68
SD	15.50	13.66	14.86	13.93
PPVT				
M	105.66	109.70	107.79	110.58
SD	14.98	11.87	13.69	11.51
Range	75–136	86–130	79–136	86–130

SD: standard deviation; FIQ: full-scale IQ (Wechsler Abbreviated Scale of Intelligence (WASI); Wechsler, 1999); VIQ: verbal IQ (WASI; Wechsler, 1999); PIQ: performance IQ (WASI; Wechsler, 1999); PPVT: Peabody Picture Vocabulary Scale (Dunn and Dunn, 2007).

Experiment 1

In Experiment 1, participants with ASD and control participants were given word pairs to learn and were then asked to predict future recall (JOL) either immediately after the presentation of the pairs (immediate JOL) or after a delay (delayed JOL). The exploratory aims of this first experiment were to see whether participants with ASD would make accurate JOL predictions and also whether JOL accuracy in participants with ASD would exhibit sensitivity to the time at which JOLs are elicited. Indeed, studies in healthy adults (Nelson and Dunlosky, 1991) and in TD children (e.g. Koriat and Shitzer-Reichert, 2002; Schneider et al., 2000) showed better JOL accuracy when the judgments were made after a delay. According to the monitoring-retrieval hypothesis proposed by Dunlosky and Nelson (1992), this *delayed-JOL-effect* occurs because delayed JOLs are based on information retrieved from long-term memory, which is more similar to the information actually retrieved from long-term memory when searching for the target word. On the contrary, immediate JOLs would be based on information issued from short-term memory and would therefore have a limited validity in predicting future recall from long-term memory. The *delayed-JOL-effects* thus show that JOLs are affected by the type of information retrieved from memory at the time of judgment.

Method

Participants. A total of 21 adolescents with ASD (18 males, 3 females) and 21 control participants (17 males, 4 females) were included in this study. Table 1 shows their characteristics. There were no group differences on age ($t(40) = 1.52$, $p = .14$, $d = 0.47$), full-scale IQ (FIQ; $t(40) = 1.07$, $p = .29$, $d = 0.33$) and PIQ ($t(40) = 0.02$, $p = .98$, $d = 0.005$) (WASI; Wechsler, 1999). There was a group difference approaching significance in VIQ, with the ASD group achieving lower scores than the TD group ($t(40) = 1.88$, $p = .06$, $d = 0.58$). However, the groups did not differ on *receptive vocabulary*, as measured by the Peabody Picture Vocabulary Test (PPVT; Dunn and Dunn, 2007) ($t(40) = 0.95$, $p = .34$, $d = 0.29$).

Materials and design. The procedure was similar to Schneider et al. (2000); however, instead of pictures, word pairs were used. The study was based on a 2 (autism vs control) × 2 (immediate vs delayed JOL) mixed design. In the immediate task, predictions of future recall were made directly for each to-be-remembered cue–target pair (e.g. *dog*–STRAW) by presenting the cue word (*dog–?*). In the delayed task, participants studied all the pairs before making individual predictions of future recall for each pair (again using the cue) after a delay of about 2 min. Within each task, there were two study-test blocks. The materials and presentation orders were fully counterbalanced.

A total of 48 nouns were selected from the MRC Psycholinguistic Database (Coltheart, 1981). They were divided into 24 unrelated cue–target words and were presented in two subsequent blocks of 12 word pairs, each in a counterbalanced order. Two lists of 12 word pairs were used for the immediate JOLs, whereas the remaining two were used for the delayed condition. In all, 24 words were used as

Table 2. Proportion of items correctly recalled and judgments-of-learning (JOL) accuracy gamma scores for the individuals with ASD and controls in Experiment 1.

	ASD (n = 21)	Comparison (n = 21)
Recall		
Immediate recall	.36 (.26)	.34 (.23)
Delayed recall	.32 (.24)	.34 (.24)
JOL		
Immediate JOL-gamma	.05 (.11)	.27 (.11)
Delayed JOL-gamma	.86 (.06)	.87 (.06)

ASD: autism spectrum disorder.

cues and the remaining 24 as targets. A *t*-test was run to ensure that cues and targets matched in terms of age of acquisition (between 100 and 600; Gilhooly and Logie, 1980, where 100 × 1 rating corresponds to 0–2 years of age) and concreteness (between 600 and 700; Pavio et al., 1968). No difference was found either for age of acquisition ($t(47) = 0.79$, $p = .43$, $d = 0.003$, m = 274.17, SD = 72.22 for cues; m = 287.42, SD = 82.15 for targets) or concreteness ($t(47) = 1.28$, $p = .21$, $d = 0.22$, m = 613.69, SD = 69 for cues; m = 611.67, SD = 9.13 for targets). The items were of either high or low written frequencies (Kucera and Francis, 1967). To ensure that the items were equally distributed in terms of *written* frequency across the four lists, four groups of words were formed and a one-way analysis of variance (ANOVA) was conducted. The analysis revealed no difference between the word sets ($F(3, 80) = 0.21$, $p = .85$).

Procedure. Participants were tested individually and they all took part in two separate tasks: an immediate JOL task and a delayed JOL task. Tasks order and lists were counterbalanced.

Immediate JOL. During the learning phase, participants studied each pair for 8 s. Immediately after studying each pair, they were re-presented with the cue word and asked to make a JOL by predicting whether in about 5 min they would be able to recall the target word when shown the cue word. They provided a dichotomous Yes/No answer (Schneider et al., 2000; Souchay et al., 2000, 2004). In other words, they were giving a Yes JOL if they thought they would be able to recall the item and a No JOL if they thought they would not be able to recall the item. After the learning and JOL phase, participants completed a 5-min filler task (participants were given free time to try to solve the Rubik's cube). Following this filler task, participants were tested with cued recall. They were presented with the cue word only and were asked to recall verbally the corresponding target. The cues were presented in the same order as in the study list. The same procedure was repeated for the next block of 12 items.

Delayed JOL. This procedure was identical, except there was no re-presentation of the cue and no JOL made immediately after study. Instead, after having studied all items, the participants were re-presented with the cue words individually and asked to give a JOL for each cue (Dunlosky and Nelson, 1992). The cues were presented in the same order as in the study list. Again, they provided a Yes/No answer. The delay between studying the items and making the JOLs was approximately 2 min. Again, there was a 5-min retention interval (Rubik's cube) before test. The second experimental block of 12 items followed.

The experiment was run on Microsoft PowerPoint. Prior to each condition, the participants were given a practice trial on three word pairs in order to familiarize themselves with the procedure.

Results and discussion

Recall. Preliminary analyses of recall (proportion of correctly recalled items) revealed no effect of block, and therefore, the data was collapsed across trials (Schneider et al., 2000). Means and SDs are presented in Table 2. A 2 (group) × 2 (immediate/delayed recall) ANOVA revealed no significant group effect ($F(1, 40) = 0.002$, $p = .97$, $\eta_p^2 = .001$), as well as no condition effect ($F(1, 40) = 0.46$, $p = .50$, $\eta_p^2 = .01$). The interaction was also not significant ($F(1, 40) = 0.70$, $p = .41$, $\eta_p^2 = .02$). Therefore, recall performance did not vary between groups or across immediate and delayed JOL conditions.

JOL: calibration. Our first analysis compares the level of prediction in each group. In this case, each Yes JOL made by a participant is an indication that they think they will remember that word. We examined the proportion of Yes judgments for each participant in each condition. For example, if a participant makes 22 Yes judgments (91% of 24 items), arguably, this translates as a prediction that they will recall .91 of the items studied. In the immediate condition, the groups predicted that they would recall most of the items in the list (m = 0.71, SD = 0.23 for ASD; m = 0.63, SD = 0.20 for typical) compared to recall of .36 and .34 for the groups, respectively. Thus, both groups overestimate their performance by about 30% in the immediate condition (35% for TD and 29% for ASD), but the ASD group is no worse in this regard. In the delayed condition, the mean proportion of Yes predictions was lower (m = 0.45, SD = 0.28 for ASD; m = 0.47, SD = 0.22 for typical). A 2 (group) × 2 (immediate/delayed) ANOVA on these data showed no main effect of group ($F(1, 40) = 0.18, p = .678, \eta_p^2 = .004$), a significant main effect of condition ($F(1, 43) = 39.51, p < .001, \eta_p^2 = .50$) and a non-significant interaction ($F(1, 40) = 2.05, p = .15, \eta_p^2 = .05$).

In sum, both groups overestimate their performance, and the delayed condition shows both groups significantly revise downwards their predictions of future recall. Since the order of immediate and delayed conditions were counterbalanced, this effect is due to the delay period, not due to some general revising of predictions as one learns the task. There is no statistical suggestion of a difference between the ASD and controls in the number of Yes predictions made. Thus far, the ASD group has performance and a level of prediction which are also no different from controls. Both groups also see a significant change in predictions over a delay, as expected. Arguably, both groups are thus equally poorly calibrated.

JOL: relative accuracy. The critical issue in metacognition is whether items judged as more likely to be recalled actually are more likely to be recalled, the relative accuracy of a participant. This is an issue which is independent of calibration (e.g. Nelson and Dunlosky, 1991). This critical JOL accuracy was measured by means of Goodman–Kruskal gamma non-parametric correlations for each participant (Nelson, 1984). Essentially, a gamma produces a coefficient between −1 and 1, with large positive values corresponding to a strong association between memory performance and metamemory judgments (indicating accurate metamemory), while negative values show an inverse relationship (indicating inappropriate metamemory). The gamma correlation (G) consists of comparing the proportion of correct predictions and incorrect predictions ($G = (ab - bc)/(ab + bc)$) with the following: (a) correct recall for Yes JOLs, (b) incorrect recall for Yes JOLs, (c) correct recall for No JOLs and (d) incorrect recall for No JOLs. However, with a Yes/No binary prediction, the measure is undefined when two of the four possible outcomes used to compute the gamma scores (a,b,c,d) are equal to 0. Therefore, as suggested by Snodgrass and Corwin (1988), the adjusted gamma was used, by adding 0.5 to each frequency and dividing it by N (number of judgments) + 1 (see Souchay et al., 2002, 2007).

The mean gamma correlations for each group and each condition are shown in Table 2. A one-sample *t*-test was first run for each group separately to see whether the gamma scores of each group are significantly different from 0. The analysis for the control group revealed that both immediate and delayed JOL gammas were different from 0 ($t(20) = 3.02, p < .05$ and $t(20) = 28, 94, p < .001$, respectively). The same result was present in the ASD group however for the delayed JOL only ($t(20) = 10.84, p < .005$). In the immediate condition, the ASD group's JOL accuracy was not significantly different from 0 and therefore at chance-level ($t(20) = 0.39, p = .70$). A 2 (group) × 2 (immediate vs delayed) ANOVA revealed no main effect of group ($F(1, 40) = 1.51, p = .23, \eta_p^2 = .03$). There was a significant effect of condition ($F(1, 40) = 84.97, p < .001, \eta_p^2 = .68$) where both groups were more accurate in the delayed compared to immediate condition, showing a *delayed-JOL-effect*. No significant interaction was found between group and condition ($F(1, 40) = 1.97, p =.18, \eta_p^2 = .04$).

To explore relative JOL accuracy further, we examined the correspondence between JOL judgments (Yes/No) and recall (category a vs c in the formula used to compute the gamma score), where JOL accuracy would be shown by Yes predictions having a significantly higher proportion of subsequent recall than No predictions. These means are presented in Figure 1.

These proportions (Figure 1) were submitted to a 2 (group) × 2 (immediate/delayed) × 2 (Yes JOL/No JOL) ANOVA. This revealed no significant main effect of group ($F(1, 40) = 2.11, p =.16, \eta_p^2 = .05$) and no significant effect of condition (immediate vs delayed) ($F(1, 40) = 0.00, p = 1, \eta_p^2 = .001$). There was no significant interaction between condition and group ($F(1, 40) = 0.00, p = 1, \eta_p^2 = .001$). There was a main effect of prediction ($F(1, 40) = 249.65, p < .001, \eta_p^2 = .86$), showing that recall was higher for words given a Yes JOL than for words given a No JOL. This is indicative of appropriate metamemory monitoring. A significant interaction between condition and judgment type was found ($F(1, 40) = 20.68, p < . 001, = .34$). Figure 1 suggests that this is due to the fact that in the delayed condition, recall is higher for Yes JOLs and lower for No JOLs. No significant three-way interaction was found ($F(1, 40) = 0.34, p = .56, \eta_p^2 = .008$). To further analyse the interaction between condition and prediction type, within-sample *t*-tests were run to compare Yes predictions in the delayed and immediate conditions (see Figure 1). For the children with ASD, the analysis revealed a significant difference between the two conditions ($t(20) = 2.30, p < .03, d = 0.69$), showing that the proportion recalled for Yes predictions was higher in the delayed than in the immediate condition. A similar pattern was observed in the control participants ($t(20) = 3.18, p < .005, d = 0.99$). The analysis for No predictions in individuals with ASD also revealed a significant difference ($t(20) = 3.65, p < .001, d = 1.05$), with the proportion recalled being higher for No predictions in the immediate than in the delayed condition. A similar pattern was found in the control participants ($t(20) = 3.18, p < .01, d = 0.99$). Note that for No predictions, metacognitive proficiency is indicated by lower levels of recall – to recall something that one predicts they will forget ultimately shows a lack of awareness.

In sum, these results show that adolescents with ASD, like control participants, are more accurate when predicting their recall after a delay, thus showing the classic

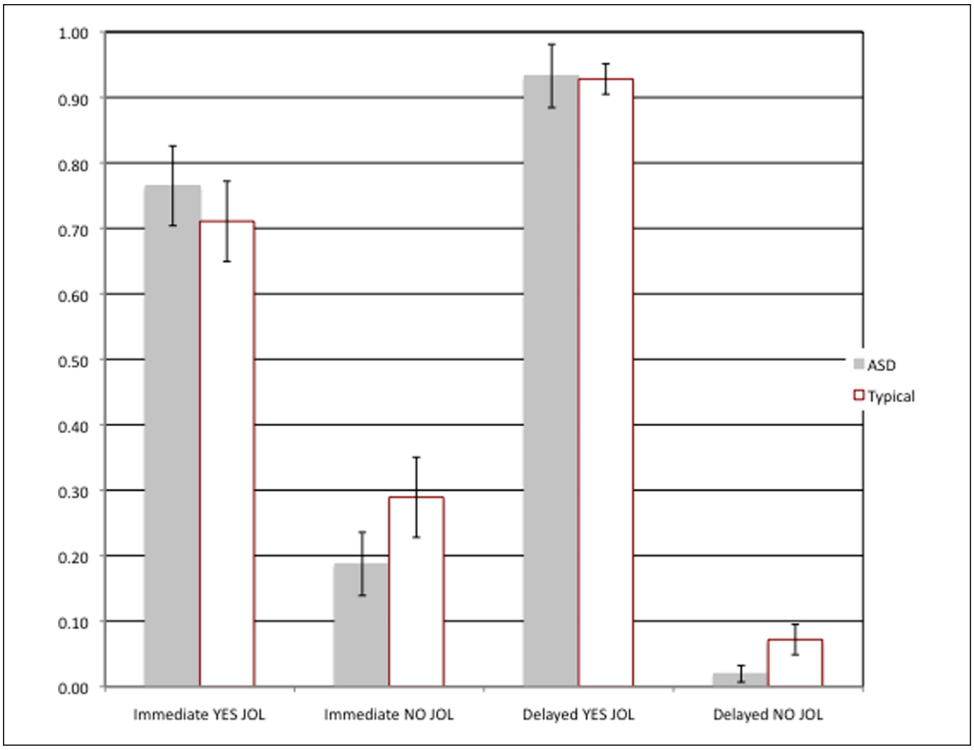

Figure 1. Proportion of correct recall for Yes and No immediate and delayed JOLs, Experiment 1. Error bars = 1 standard error of the mean.
JOL: judgment-of-learning.

delayed-JOL-effect. Furthermore, despite gamma scores not being different from chance in the ASD group for immediate JOLs, no significant group differences were observed between groups on JOL accuracy. In short, the use of this paradigm has ascertained metacognitive proficiency in the ASD sample. Their predictions of performance are in keeping with normal patterns of performance with regard to a delay, and they have patterns of objective recall performance which are in keeping with their subjective assessments of future performance. There is a tendency for both groups to overestimate their performance initially, however.

Experiment 2

Experiment 1 demonstrated for the first time in the literature that JOLs, especially those made after a delay, were predictive of subsequent recall performance in individuals with ASD. This form of relative accuracy found in both groups is critical. Indeed, as proposed by the metamemory framework of Nelson and Narens (1990), monitoring processes (as measured by JOLs) guide control processes. Through effective monitoring, learners control their cognitive resources to achieve an optimum level of performance. In this context, many studies in healthy adults have shown that JOLs influence study time allocation (Dunlosky and Connor, 1997; Mazzoni and Cornoldi, 1993; Nelson and Leonesio, 1988). These studies have shown that in self-paced learning, more study time is attributed to items previously given lower JOLs. Similarly, developmental studies showed that children, even first graders, use their JOLs to regulate study time (Lockl and Schneider, 2003).

In participants with ASD, the relation between metacognitive judgments such as JOLs and memory strategies has never been explored, and for our aim of exploring the regulation of memory processes during learning, it is a key issue. However, there has been evidence suggesting that individuals with ASD fail to regulate their memory strategies. For example, many studies indicate that people with ASD do not spontaneously use memory strategies or the characteristics of the material presented to support their encoding of the stimuli presented (Bowler et al., 2008; Gaigg et al., 2008; Smith et al., 2007). Furthermore, although Farrant et al. (1999a) showed that children with autism found it difficult to judge when to stop learning to achieve optimal memory performance, in another study in which children were asked to remember a set of pictures and had to stop learning when they felt ready to recall the material, they found that children with autism were poor at judging their ‘recall readiness’. Thus, because both monitoring of one’s own learning and the regulation of learning strategies may have an effect on memory performance (Benjamin and Bjork, 1996), the first exploratory aim of Experiment 2 was to assess whether adolescents with ASD could regulate their study time according to their JOLs. To do so, participants were asked to learn a list of word pairs, make JOLs, and then were presented with the same list of word pairs for a second trial and given the opportunity to spend as long as they wanted studying the items using a self-paced learning procedure.

The second exploratory aim of Experiment 2 was to assess whether individuals with ASD could use their knowledge regarding memory functioning and, in particular, their knowledge of the different factors influencing memory performance to make JOLs. Indeed, according to Koriat's *cue-utilization theory* (Koriat, 1993), an individual can use different types of information to make metacognitive judgments such as JOLs. For example, metacognitive judgments can be based on people's belief about their skills or about the task and thus rely on 'metacognitive knowledge' (Flavell and Wellman, 1977). In this context, many studies have shown that JOLs are based on both intrinsic cues (which are specific to the stimuli themselves, for example, the difficulty of items) and extrinsic cues (which are specific to the task, for example, the strategies used to encode the stimuli). For example, JOLs have been shown to be higher for semantically related study items than unrelated items (Matvey et al., 2006), higher for normatively easier items than harder ones (Moulin et al., 2000b) and higher for fluently generated items (Matvey et al., 2001). A similar pattern has been shown in TD children from grade 1 (6-year-olds) to 3 (8-year-olds), who give higher JOLs for easy than for difficult items (Koriat and Shitzer-Reichert, 2002; Lockl and Schneider, 2003). Therefore, the aim of this second experiment was to determine whether JOLs in adolescents with ASD were sensitive to intrinsic cues and, in particular, item difficulty. To do so, we presented lists of either concrete–concrete word pairs or abstract–abstract word pairs (Thiede and Dunlosky, 1999).

The self-paced learning paradigm used in this experiment also gave us the opportunity to measure whether or not study time allocation in individuals with ASD was sensitive to intrinsic factors. Indeed, like JOLs, study time allocation is influenced by intrinsic cues. For example, many studies have observed that participants allocate more time to more difficult items (for a comprehensive review, see Son and Metcalfe, 2000). In the developmental literature, Dufresne and Kobasigawa (1989) found that fifth (10-year-olds) and seventh (12-year-olds) graders allocated more time to study difficult items than easy items. Similarly, in autism, Farrant et al. (1999a) showed that children with ASD like TD children allocated more study time to longer lists (Span + 2) than shorter lists (Span). Here, we will thus reassess whether or not adolescents with ASD can allocate their study time according to the item difficulty.

Method

Participants. A total of 19 adolescents with ASD (16 males, 3 females) and 19 control participants (14 males, 5 females) were included in this study. Table 1 shows their characteristics. There were no group differences on age ($t(36) = 1.42$, $p = .16$, $d = .47$), FIQ ($t(36) = 0.96$, $p = .34$, $d = .28$) and PIQ ($t(36) = 0.20$, $p = .84$, $d = .06$) (WASI; Wechsler, 1999). There was a group difference approaching significance in VIQ, with the ASD group achieving lower scores than the TD group ($t(36) = 1.90$, $p = .07$, $d = .61$). However, the groups did not differ on receptive vocabulary, as measured by the PPVT (Dunn and Dunn, 2007) ($t(36) = 0.68$, $p = .50$, $d = .22$).

Materials. A total of 60 nouns were selected from the MRC Psycholinguistic Database (Coltheart, 1981) to form a list of 30 cues and 30 targets. To vary the level of difficulty across items, 15 easy: concrete–concrete and 15 difficult: abstract–abstract nouns (low in concreteness) word pairs were created (Thiede and Dunlosky, 1999). It was ensured that cues and targets were matched on age of acquisition and concreteness for each easy ($t(28) = 1.13$, $p = .90$; $t(28) = 0.20$, $p = .84$, respectively) and difficult lists ($t(28) = 0.63$, $p = .54$; $t(28) = 0.69$, $p = .49$, respectively). Considering the age of participants in our study, all 60 items were of ratings between 4 and 10 years of age (range: 169–492; Gilhooly and Logie, 1980). The word pair presentation order was randomized with a restriction that no more than 2 consecutive items could be concrete–concrete and abstract–abstract (Thiede and Dunlosky, 1999).

Procedure. The procedure was similar to the one previously used to investigate JOL and study time allocation (e.g. Dunlosky and Connor, 1997; Moulin et al., 2000a, 2011). The experiment consisted of two phases, with two separate learning trials and two separate cued recall tests. Phase 1 entailed a fixed time study phase, a delayed JOL and a cued recall phase (Nelson and Dunlosky, 1991). In Phase 2, participants were presented with the same items as in Phase 1, in a new randomized order, and were asked to study the items in their own time (self-study time allocation). This was then followed by a cued recall test (as Experiment 1). The experiment was run on E-prime which enabled accurate measurement of the self-paced study time. Prior to the actual experiment participants were provided with a 3-item practice trial to familiarize themselves with the procedure.

In Phase 1, participants were presented with word pairs for 8 s each. The cues were presented in small letters, whereas targets were presented in capital letters (e.g. easy pair: *paper–WATER*, difficult pair: *dream–FLUENCY*). After presentation of the last pair in the list, the participants were given a brief distracter task (three arithmetic problems). They were then asked to make their JOLs. Upon seeing the cue word only (e.g. *paper*–____), participants were asked, *How sure are you that you will recall the CAPITAL letter word later when you see the small letter word?* Participants were asked to make their JOLs using a hot–cold thermometer game (see Koriat et al., 2009) as well as percentage of recall likelihood. The use of scale

Table 3. Proportion of items correctly recalled and judgments-of-learning (JOLs) accuracy gamma scores for the individuals with ASD and controls in Experiment 2.

	ASD (*n* = 19)	Comparison (*n* = 19)
Recall		
Trial 1 easy pairs	.39 (.26)	.44 (.29)
Trial 2 easy pairs	.65 (.29)	.75 (.25)
Trial 1 difficult pairs	.14 (.12)	.11 (.12)
Trial 2 difficult pairs	.37 (.28)	.30 (.20)
JOL		
JOL-gamma easy pairs	.84 (.10)	.79 (.12)
JOL-gamma difficult pairs	.78 (.13)	.59 (.12)

ASD: autism spectrum disorder.

rather than binary judgments as in Experiment 1 was necessary in order to measure whether JOL magnitude changed as a function of the objective difficulty of the materials. They were required to rate their JOL on a 5-point scale (five coloured segments) presented as a colour drawing of a thermometer ranging from deep blue (very cold or 20% – *small chance I will recall the word*) to deep red (very hot or 100% – *I am completely sure I will recall the word*). We used coloured buttons on the keyboard (ranging from deep blue to deep red). An immediate cued recall test followed after the presentation of the last item. Participants were presented with the cue word only and asked to verbally recall the corresponding target (Trial 1 Recall). Phase 2 followed immediately after the last word pair was presented. Here, the same list of 30 word pairs was presented again in a randomized order; however, this time, the participants could allocate as much time as they wanted to study the items. They were instructed to:

> Now study the same word pairs for as long as you want. Press the YELLOW button on the keyboard when you think you have learned them to the best of your ability and you want to move on to the next item.

This was then followed by an immediate cued recall (Trial 2 Recall). Participants were presented with the cues and for each cue asked to retrieve the corresponding target.

Results and discussion

Recall. To investigate the memory performance a 2 (group) × 2 (word difficulty: easy vs difficult words) × 2 (Trial), ANOVA was conducted on the proportion of correctly recalled items (see Table 3). The analysis revealed no main effect of group ($F(1, 36) = 0.004$, $p = .88$, $\eta_p^2 = .001$). There was a main effect of trial ($F(1, 36) = 174.4$, $p < .001$, $\eta_p^2 = .82$) with the expected effect that more words being recalled on Trial 2 than Trial 1. There was also a main effect of word difficulty ($F(1, 36) = 144.68$, $p < .001$, $\eta_p^2 = .80$) with both groups showing higher recall rates for objectively easy than difficult pairs (see Table 3 for means). No significant trial by group interaction was found ($F(1, 36) = 0.003$, $p = .649$, $\eta_p^2 = .005$), but the interaction between group and word difficulty was significant ($F(1, 36) = 5.0$, $p < .03$, $\eta_p^2 = .12$), with differences between groups occurring mainly on the easy pairs showing that the ASD group recalled fewer words. Furthermore, a significant interaction was found between trial and word difficulty ($F(1, 36) = 7.1$, $p < .01$, $\eta_p^2 = .165$), showing that the difference between the recall for easy and difficult words was more marked at Trial 2; in short, the participants learn more of the easier pairs. The three-way interaction failed to reach significance ($F(1, 36) = 0.034$, $p = .09$, $\eta_p^2 = .08$).

JOL sensitivity. We anticipated here that the magnitude mean JOLs (JOLs were made on a 5-point percentage scale) would be sensitive to word difficulty and would be lower for the difficult list. This was a critical issue as the calibration of JOLs was rather poor in both groups in Experiment 1. A 2 (group) × 2 (easy vs difficult) ANOVA was conducted to investigate whether the ASD group's JOLs were sensitive to varying item difficulty, that is, whether adolescents with ASD and controls changed their JOLs with varying item difficulty. The analysis showed no main effect of group ($F(1, 36) = 0.001$, $p = .98$, $\eta_p^2 = .001$). There was a main effect of word difficulty ($F(1, 36) = 63.76$, $p < .001$, $\eta_p^2 = .64$), that is, both groups had higher JOLs for easy (m = 2.56, SD = 0.19 for ASD; m = 2.69, SD = 0.14 for TD) than difficult words (m = 2.06, SD = 0.19 for ASD; m = 1.95, SD = 0.14 for TD). No interaction was found between group and JOL for word difficulty ($F(1, 36) = 2.49$, $p = .12$, $\eta_p^2 = .06$). Both groups made JOLs which were sensitive to the objective qualities of the materials.

JOL accuracy. Like in Experiment 1, relative accuracy was calculated using the Goodman–Kruskal gamma score (Nelson, 1984). We computed gamma scores for JOL for both easy and difficult words separately. A 2 (group) × 2 (easy/difficult gamma) ANOVA showed no main effect of group ($F(1, 26) = 0.79$, $p = .38$, $\eta_p^2 = .001$). There was also no

Table 4. Mean study time in seconds for easy and difficult words, as well as recalled and non-recalled words for the individuals with ASD and controls in Experiment 2.

	ASD (n = 19)	Comparison (n = 19)
Study time – easy vs difficult words		
Easy words	4.87 (2.42)	4.04 (1.95)
Difficult words	6.03 (2.35)	5.76 (2.13)
Study time – recalled vs non-recalled words		
Recalled words	4.87 (3.85)	4.03 (3.01)
Non-recalled words	6.03 (4.98)	5.75 (4.71)

ASD: autism spectrum disorder.

difference between accuracy of JOL for easy versus difficult words ($F(1, 26) = 1.81, p = .19, \eta_p^2 = .64$). Finally, there was no interaction between JOL accuracy and group ($F(1, 26) = 0.49, p = .49, \eta_p^2 = .018$). Means are displayed in Table 3.

Then, accuracy was again measured by looking at the correspondence between JOL judgments and recall performance. The judgments were split between JOLs that were low (ratings of 1 and 2), moderate JOLs (rating of 3) and high JOLs (ratings of 4 and 5) (e.g. Mazzoni et al., 1990). JOL accuracy would be reflected in higher recall rates for higher JOLs. A 2 (group) × 3 (JOL rating: low, moderate or high) ANOVA revealed no main effect of group ($F(1, 36) = 0.16, p = .689, \eta_p^2 = .64$), but a significant main effect of JOL rating ($F(2, 72) = 228.3, p < .001, \eta_p^2 = .001$). No significant interaction was found ($F(2, 72) = 0.12, p = .883, \eta_p^2 = .88$). In other words, for both groups, recall was higher for higher JOLs. More precisely, no differences were found between recall for low or moderate JOLs in adolescents with ASD ($t(18) = 1.27, p = .21$, m = 1.47, SD = 0.34 for low JOLs; m = 0.89, SD = 0.37 for moderate JOLs) and in controls ($t(18) = 0.152, p = .88$, m = 1.52, SD = 0.34 for low JOLs; m = 1.47, SD = 0.37 for moderate JOLs). However, significant differences were observed between recall for moderate JOLs and high JOLs, with higher recall rates for higher JOLs for both adolescents with ASD ($t(18) = 4.81, p < .001$, m = 5.52, SD = 0.98 for high JOLs) and controls ($t(18) = 3.97, p < .001$, m = 5.63, SD = 0.98 for high JOLs).

Study time allocation. We first ran a one-way ANOVA on the total time (in seconds) allocated for all pairs. No group difference was found ($F(1, 36) = 0.15, p = .70, \eta_p^2 = .004$), that is, the ASD group (m = 11.02, SD = 9.19) allocated the same amount of study time as typical children (m = 10.51, SD = 8.68).

We then ran two sensitivity analyses of study time. Our first analysis looked at total study time for easy versus difficult words for both groups (for means and SDs, see Table 4). A 2 (group) × 2 (easy vs difficult) analysis revealed no significant main effect of group ($(1, 36) = .16, p = .70, \eta_p^2 = .004$). However, there was a main effect of difficulty of the pairs ($F(1, 36) = 7.76, p < .05$, = .177), but no difficulty by group interaction ($F(1, 36) = 0.26, p = .62, \eta_p^2 = .007$). These results show that both typical and ASD groups spent significantly more time on the difficult word pairs.

Our second analysis looked at study time for recalled versus non-recalled words on Trial 1 (see Table 4). A 2 (group) × 2 (recalled vs non-recalled) ANOVA showed no main effect of group ($F(1, 36) = 0.81, p = .38, \eta_p^2 = .021$), but a main effect of recall status ($F(1, 36) = 15.24, p < .001, \eta_p^2 = .297$), that is, both the typical and ASD groups spent more time studying pairs that were subsequently non-recalled than the recalled pairs. No significant interaction was found between recall status and group ($F(1, 36) = 0.58, p = .45, \eta_p^2 = .015$). Finally, we also ran within-participants correlations between JOL magnitude and the amount of study time allocated to the pairs. A negative correlation was obtained for both groups between JOL magnitude and study time, showing that both groups spent more time on the items that were given lower JOL ratings (r = −.19 for ASD; r = −.24 for typical). A one-way ANOVA showed no group differences on this measure ($F(1, 36) = 0.26, p = .62, \eta_p^2 = .012$). Thus, there were no group differences in the relation between study time allocated and JOLs given to word pairs. Most importantly, one-sample t-tests showed that these mean correlations were significantly different from 0 for both groups (ASD: $t(19) = 22.14, p = .002$; control: $t(19) = 45.02, p = .001$). Thus, both groups, on average, showed a reliable relationship between their study time allocation and their JOLs.

In sum, Experiment 2 confirmed the findings from the first experiment in that adolescents with ASD were accurate at predicting their memory performance after a delay (delayed JOL). The novelty of this second experiment was to look at JOL sensitivity to determine whether or not JOLs in adolescents with ASD would be sensitive to the factors that affect memory performance. The findings clearly showed that JOLs given by adolescents with ASD varied according to word difficulty. This second experiment also 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).

One final issue from the two experiments is that we have not found any group differences in memory performance, and that may contribute to the finding that there are no group differences in metamemory accuracy. First, note that the predictions and performance show significant within-group effects, such that these are genuine findings of proficiency rather than null effects. Second, as an example, and to examine the effect of poor recall performance, we selected the 10 lowest performing members of the ASD group in Experiment 2 and formed a new subgroup. This ASD subgroup showed a significantly lower recall on Trial 1 (m = 3.30, SD = 1.49 items correct; range = 1–5) compared to controls (m = 7.84, SD = 5.81; $t(27) = 2.41$, $p < .002$, $d = 1.07$, range = 1–19). However, there was still no group difference in the gamma correlation, which was actually rather high (m = 0.91, SD = 0.14; $t(27) = 0.74$, $p = .46$, $d = 0.33$). Note that the means are actually in the reverse direction – if anything, this lower performing ASD subgroup has numerically higher gammas than controls. This suggests that even people with ASD with significantly lower recall than controls can still adequately gauge their performance. In other words, despite performing poorly on the recall task, this ASD subgroup was able to accurately predict that they were performing poorly.

General discussion

To date, studies of autism have revealed that adolescents with ASD have good knowledge of memory functioning in general (Farrant et al., 1999b; Wojcik et al., 2011). However, whether or not children with ASD can efficiently monitor and control their memory performance has rarely been explored. Experiment 1 showed that both groups overestimate their performance, and the delayed condition shows both groups significantly revise downwards their predictions of future recall. Regarding JOL accuracy, as measured by gamma scores, both groups showed the classic *delayed-JOL-effect* of greater accuracy of JOLs after delay. Finally, despite gamma scores not being different from chance in the ASD group for immediate JOLs, no significant group differences were observed between groups on JOL accuracy either immediately or after a delay. Experiment 2 confirms a lack of group differences on JOL accuracy and demonstrates that individuals with ASD could also use JOLs to control their learning strategies and, in particular, the allocation of study time. However, not all previously published studies show that metacognition is preserved in autism, and therefore, we now briefly review these few studies and tentatively offer a framework by which to understand these results, and some suggestions for future studies.

First, this study showed in two experiments that individuals with ASD could accurately predict their subsequent recall performance and were, like control participants, especially accurate when these predictions were made after a delay (a delayed JOL). As described by Koriat (1997), when making JOLs, individuals use their metacognitive knowledge to make their predictions, such as their knowledge about the effect of the task (extrinsic cues) or their knowledge about the effect of the specific characteristics of the stimuli presented (intrinsic cues). A couple of studies have shown that children with ASD have a good knowledge of the factors that might affect memory performance (Farrant et al., 1999b; Wojcik et al., 2011). The results in Experiment 2 confirmed these findings. Indeed, Experiment 2 demonstrated that JOLs in people with ASD varied according to item difficulty in that easier items were given higher JOLs (concrete–concrete word pairs). In other words, people with ASD used intrinsic cues to guide their judgments and accurately predict that abstract word pairs will be more difficult to learn, and thus recall, than concrete word pairs. Similarly, children with ASD changed their study time according to the item difficulty, thus showing their knowledge of the impact of the task difficulty on their memory performance and their ability to respond to this change in difficulty. We thus suggest that JOL accuracy in autism found in this study reflects or can be explained by the fact that individuals with ASD have good knowledge of the factors influencing memory performance (intrinsic and extrinsic cues).

However, these results contrast with Wilkinson et al.'s (2010) findings showing a deficit in individuals with autism when asked retrospectively to estimate the accuracy of their answer (JOC). These studies differ in the memory paradigm used, the material (faces vs words) and also the metacognitive judgments used (JOCs vs JOLs). The main difference with Wilkinson et al.'s (2010) study is the memory impairment. Indeed, while in this article individuals with ASD were assessed on a memory task known not to be impaired in ASD (Ambery et al., 2006; Bowler et al., 1997; Gardiner et al., 2003; Minshew and Goldstein, 2001; Mottron et al., 2001; Williams et al., 2006), and indeed we did not show any memory impairments, memory performance was impaired in the study by Wilkinson et al. (2010). These findings thus raise the question as to whether memory impairment explains metamemory inaccuracy in ASD. This question relates to an important debate in the metamemory literature regarding the relationship between memory performance and metacognitive judgments. In this context, Koriat (1993) suggested that metacognitive judgments derive from *target accessibility*, described as the amount of partial information related to the target retrieved while searching for the item. In other words, when failing to recall the target, the ability to retrieve peripheral information related to the target will guide metacognitive judgments. For example, several studies have shown that metacognitive judgments are associated with the retrieval of structural–phonological partial information, such as the initial letter (Blake, 1973; Koriat, 1993), or semantic-related information, such as the connotative meaning (e.g. Eysenck, 1979; Koriat, 1993; Koriat et al., 2003; Schacter and Worling, 1985). Furthermore, there is evidence suggesting that metacognitive accuracy relies on the quality of the encoding processes. In this context, a number of studies have demonstrated that certain variables that affect memory trace also affect metacognitive performance (Carroll and Nelson, 1993; Kelemen and Weaver; 1997; Kelley and Sahakyan, 2003; Koriat; 1993; Lupker et al., 1991; Nelson et al., 1982), suggesting that metacognitive accuracy and memory are not in fact independent processes (Koriat, 1993). For example, Nelson et al. (1982) showed that the amount of overlearning increased not only memory performance but also FOK accuracy. Sacher et al. (2009) showed that divided attention at encoding altered memory performance as well as FOK accuracy. These findings thus suggest that the quality of memory encoding contributes to make accurate metacognitive judgments (for a similar argument in ageing, see Hertzog et al., 2010). As a result, in autism, difficulties in encoding certain types of material could potentially lead to inaccurate metacognitive judgments. For example, recent studies showed that autism is characterized by a domain-specific memory impairment for faces (Hedley et al., 2011). Of particular interest to this study, Wilkinson et al. (2010) showed that children with ASD had a different style of processing faces when learning new faces, suggesting that children with ASD use different and fewer information when asked to remember faces. This could explain why Wilkinson et al. (2011) reported inaccurate JOC in individuals with ASD. Indeed, a reduction in the quality of the encoding of faces could directly affect metacognitive judgments such as JOC by reducing the amount of partial or peripheral information related to the target on which the judgment is made. These findings thus suggest that memory impairments might lead to metacognitive inaccuracy in autism. However, in this study, when a group of children with ASD performing poorly on the memory task was isolated, our findings showed that their metacognitive accuracy still did not differ from controls. In other words, children and adolescents with ASD who do present low memory performance can accurately predict their low recall and thus gauge their memory performance. This result suggests that low memory performance does not impact JOL accuracy in children with autism. To summarize, low memory performance in ASD might have an impact only on JOCs and not JOLs. Unlike JOLs, made while encoding the information or shortly after, JOCs are made at the retrieval stage. Here, we would like to introduce the idea that metacognitive judgments in ASD would be more impaired when made at the retrieval stage. For example, we recently showed inaccurate FOK judgments in adolescents with autism on a very similar PAL task (Wojcik et al., 2013). The main characteristic of these FOK judgments is that they happen at the retrieval stage and participants are asked to predict the future recognition of an item that they could not recall. These findings also resonate with the metacognition literature showing that different metacognitive judgments rely on different factors (Kelemen et al., 2000). For example, judgments made at encoding, such as JOLs, might rely more on cues related to the type of task or material used (intrinsic and extrinsic cues), while judgments made at the retrieval stage might rely more on target accessibility and thus memory trace (Souchay and Isingrini, 2012).

One way to explore whether or not memory impairments in autism lead to metacognitive inaccuracy would be to concentrate on memory tasks impaired in autism. For example, the memory research in autism suggests that the memory problems found in this population might arise due to a lack of recollection, defined as the conscious retrieval of contextual details associated to the target (e.g. Mandler, 1980, 2008; Yonelinas, 2002). Support for this idea comes from the studies in children with ASD which assess recollection objectively by measuring the ability to retrieve contextual information regarding a given target (Bowler et al., 2004; Hala et al., 2005; Lind and Bowler, 2009; Millward et al., 2000; Russell and Jarrold, 1999 but see Farrant et al., 1998; Gras-Vincendon et al., 2007; Hill and Russell, 2002; Russell and Hill, 2001; Williams and Happé, 2009). Furthermore, studies using the Remember/Know paradigm (Tulving, 1985) in adults with AS all showed a reduced number of Remember judgments, suggesting impaired recollection (Bowler et al., 2000, 2007; Tanweer et al., 2010). This lack of recollection in autism is interesting when considering a more recent development in the metacognition literature suggesting that recollection could mediate different metacognitive judgments and, in particular, judgments made at retrieval (Hicks and Marsh, 2002; Sacher et al., 2009; Souchay et al., 2007). In fact, a new programme of research should look at metacognitive accuracy in autism on memory tasks relying on recollection. One area where recollection is of interest is in the retrieval of personal experiences – autobiographical memory. Indeed, autobiographical memory and the ability to imagine future events are also compromised in autism (see Lind and Bowler, 2009), but whether or not people with autism are aware of this is not known.

Finally, several studies in autism have revealed that individuals with autism fail to use memory strategies (Bowler et al., 1997, 2000). The aim of the second experiment in this article was to explore whether this could be potentially caused by a metamemory failure and, in particular, difficulties in estimating memory performance, for example, how well items have been learnt (JOL). The results showed that adolescents with autism allocated the same amount of time as typical children to the items. Furthermore, both groups were found to spend more time on the items that were given lower JOL ratings, thus suggesting that children and adolescents with ASD were able to use their metacognitive judgments to appropriately allocate their study time. These findings suggest that adolescents with ASD can self-regulate their learning (for a recent model of self-regulated learning, see Metcalfe, 2002). However, some evidence suggests that people with HFA are in fact able to utilize memory strategies, but that they do not do so spontaneously

(Gaigg et al., 2008). We suggest here that asking individuals with ASD to make judgments on their learning, in other words to estimate their memory performance while learning the material, might trigger the correct use of memory strategies. This finding would be in line with previous distinctions between implicit and explicit learning in autism in that individuals with autism can do tasks when asked explicitly to do them but not when the request is implicit (see Boucher et al., 2012). This idea will of course need further exploration but could be of particular importance to guide strategy usage in autism.

Conclusion

The main findings in this study were first a lack of group differences in JOL accuracy and also a preserved ability in adolescents with autism to use metacognitive judgments to control their learning strategies (study time). These findings are relevant from an educational point of view as awareness of learning has been found to have pronounced effects on memory and learning (Flavell, 1979; Schneider, 1999). Indeed, research with children and adolescents suggests that awareness of memory performance affects academic performance (Pierce and Lange, 2000). Other studies have shown that children's ability to monitor their memory effectively affects the accuracy of their responses when asked to provide information about an event (e.g. Roebers and Fernandez, 2002; Waterman and Blades, 2011; Waterman et al., 2004). Thus, knowing that at least some metacognitive competences are preserved in adolescents with ASD could potentially guide teachers in choosing the most appropriate teaching methods.

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