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Memory and metamemory for actions in children with autism: Exploring global metacognitive judgements

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ABSTRACT

Background: Standards in education emphasize the role of metacognition in successful academic outcomes for those with and without learning challenges. Research into metamemory in Autism Spectrum Disorder (ASD) has produced mixed outcomes, with some studies finding children with ASD to have spared metacognitive accuracy and others finding it impaired. While most research has used item-by-item metamemory judgements, the novelty of the current study was to use global judgments-of-learning (global JOLs).
Method: Twenty-three children with and twenty without ASD were presented with two lists of action words during a learning phase and were asked to either act out the words in a self-performed task or just listen to them being read aloud in a verbal task (control condition). Typically, self-performance produces memory benefits called the *enactment effect.* For both tasks, children also made pre-learning and post-learning global JOLs, stating how many words they thought they would recall.
Results: Both groups demonstrated the enactment effect, but neither predicted its beneficial effect. Compared to controls, participants with ASD were found to be less accurate in predicting their future memory performance, specifically in the self-performed task. Both groups were comparable in terms of metacognitive monitoring.
Conclusions: Overall, the findings suggest that success or failure in metacognitive tasks in ASD might depend on task difficulty, and the type of metacognitive judgement used.

What this paper adds?

Metacognition research in autism has focused on exploring item-by-item judgements and produced mixed outcomes. The novelty of this research was to report the use of global judgments-of-learning (global JOLs) to better understand the status of metamemory in autism. Global JOLs allowed us to measure learners' knowledge about their own memory performance and their awareness of the different task characteristics that can impact memory performance. To vary memory performance, this study was based on the Self-Performance task effect, whereby enacting the to-be-remembered material boosts learners' memory performance. To measure metacognitive knowledge of this effect, participants were asked to predict their performance both before and after the task. We found that the ASD group inaccurately estimated their performance before, but not after the task. Also, while both groups' performance was

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improved by the enactment, neither group predicted its beneficial effect. Our findings point to the fact that memory and metamemory strengths and weaknesses in children with autism might depend on type of memory task used and type of metamemory judgments used, an observation that educators might want to take into account when planning for classroom support for children with autism.

1. Introduction

Metacognitive skills are important for successful learning, especially for people facing learning challenges (Bosson et al., 2010). There has been an increase in research into metamemory in children with autism spectrum disorders (ASD). Metamemory, i.e., our beliefs, reflections, and knowledge about memory (Flavell, 1979), has been linked to the theory of mind, our ability to understand other's mental states (Frith & Happé, 1999), as well as to executive functioning, the higher order co-ordination of cognitive processes (e.g., Souchay, Isingrini, & Espagnet, 2000). All of these functions have been shown to be affected in ASD (e.g., Berenguer, Roselló, Colomer, Baixauli, & Miranda, 2018) and are often attributed to a general reduction in self-perception (Furlano et al., 2015) as well as diminished ability to metarepresent (Baron-Cohen, 2001). Several studies have demonstrated that children and adolescents with ASD are unaware of their symptomatology (Johnson, Filliter, & Murphy, 2009). For example, children with ASD claim to have greater social and communication skills than reported by their parents (Knott et al., 2006) and teachers (Vickerstaff et al., 2007). The novelty of our study was to explore whether these general problems in awareness in ASD could be explained by an inability to reflect on their own performance in a memory task. Examining metamemory is furthermore important for learners because the lack of awareness of one's own memory strengths and weaknesses might influence the ability to incorporate the feedback from the task and to adjust the behavior accordingly (McQuade et al., 2011).

Metamemory can be measured using learners' subjective evaluations about their memory performance (Koriat & Levy-Sadot, 1999). These judgements can be reported item-by-item, measuring the ability to *monitor* one's own performance on an 'on-line' task or in a global manner, reflecting the participants' *general impression* about their functioning (Nelson & Narens, 1990). Research in ASD has used item-by-item paradigms in children aged 9–17. Using confidence judgements (Koriat, Lichtenstein, & Fischhoff, 1980), for example, studies have shown individuals with ASD to be inaccurate in evaluating the correctness of their answers (for an overview see Williams, Bergström, & Grainger, 2018) and in making predictions about their performance after retrieval failure (Grainger, Williams, & Lind, 2014; Wojcik, Moulin, & Souchay, 2013) in evaluations known as Feeling-of-Knowing judgements (Hart, 1965). However, Judgements-of-learning (JOL, Dunlosky & Nelson, 1992), made during encoding, appeared to be intact in ASD in a study carried out by ourselves (Wojcik, Waterman, Lestié, Moulin, & Souchay, 2014) and in a study by Grainger, Williams, and Lind (2016).

In our previous study, using a very similar cohort of participants to the present study, in terms of size, age of children and IQ matched controls, we investigated metamemory for school-like instructions (Wojcik, Allen, Brown, & Souchay, 2011). We found that children with ASD were as accurate as controls when they made global confidence judgements, showing the ability to judge the accuracy of their performance after having completed the task. The novelty of the current study, however, was to examine whether children with ASD can accurately predict their future memory performance using global Judgments of Learning (global JOLs). A couple of studies by Furlano et al. (2015) and Furlano and Kelly (2019) looked at children's self-perception using so-called global predictions conducted prior to and after performing familiar mathematics and verbal school tasks. The authors found that children with ASD tended to overestimate their performance more than controls when rating their competence. The current study used similar procedures to Furlano and Kelly (2019) in terms of the pre-post format of predictions, but in a specific memory task that was novel to the participants.

A global JOL procedure allowed us to examine metamemory knowledge. *Knowledge*, here, has been referred to by metacognition researchers as participants' *awareness* or *perceptions* of factors that might impact memory performance (known as knowledge about one's own memory performance; e.g., Koriat, 2007). In line with the findings that suggest impairment in self-perceptions more generally in ASD (e.g., Johnson et al., 2009) as well as impairments in self-perceptions of performance in specific academic tasks (Furlano et al. 2015; Furlano & Kelly, 2019), we predicted that knowledge about memory performance would be impaired in ASD.

Paradigms such as global JOLs also permit researchers to measure individuals' ability to update their knowledge about memory through *metacognitive monitoring*, which is participants' ability to modify their judgments after receiving feedback from the task. Monitoring is typically measured by looking at the shift in pre- to post-learning judgements. According to Koriat and Levy-Sadot (1999) post- learning predictions should be more accurate, because they are based on the experience derived from learning the material, while pre- learning predictions are based on the participants' prior knowledge regarding memory function. Furlano et al. (2015) found that children with ASD did not become more accurate at post-performance prediction, showing a deficit in metacognitive monitoring in an academic task. However, using very similar procedures as we used in the current study, it has been found that even individuals with Alzheimer Disease with moderate cognitive impairments became increasingly more accurate in their metacognitive memory monitoring when exposed to multiple trials (e.g., Silva, Pinho, Macedo, Souchay, & Moulin, 2017). We thus predicted that, as in our previous confidence judgment study (Wojcik et al., 2011), children with ASD would show a significant improvement in accuracy from pre- to post-learning predictions as a result of being exposed to the task.

Using a developmental approach, Bertrand, Moulin, and Souchay (2017) showed that children aged 4 could somewhat monitor their performance on a memory span task, even if they did not reach perfect accuracy. However, this study also showed that by the age of 12 children could accurately predict their span performance without the need of feedback, suggesting, therefore, that repeated metamemory monitoring led them to learn about their memory capacity. To take into consideration the existence of these developmental trends on metamemory accuracy, the relationship between global JOL accuracy and age in ASD and typical development was also explored in the present study. Although scarce, some research indicates the existence of developmental trends in metacognitive accuracy in people with ASD. Wilkinson et al. (2010), for instance, found children with ASD to be less accurate in their confidence judgements compared to adults with ASD. Thus, while we predicted that children with ASD in our study would be less accurate in their judgements than controls, we expected their accuracy to increase with age.

Finally, JOL procedures also allowed us to assess metacognition for different task variables which reflects *knowledge* about task characteristics (e.g., Moulin, Perfect, & Jones, 2000), referred to as the sensitivity approach. In the sensitivity approach (Moulin, 2002) it is argued that one way to measure metacognition is to look at shifts in predictions made according to variables which are known to influence performance. If a prediction changes according to a factor which is known to affect performance, this implies that the participant was metacognitively sensitive to the factor in question. We examined children's ability to predict a well-established effect on memory performance: the enactment effect, reflected in an improved memory performance for self-performed tasks in comparison to verbally presented words (verbal task). This effect occurs because the self-performed task combines sensory/visual/auditory cues which results in stronger memory representations. In our previous study (Wojcik et al., 2011) we showed that children with ASD benefited from the self-performed task (see also e.g., Grainger, Williams, & Lind, 2014), thus we expected similar results in the current study. In terms of meta-awareness of this effect, we have also previously demonstrated that children with ASD had greater confidence in the correctness of their recall in the self-performed task condition than in the verbal task condition, but their global confidence judgements were made retrospectively and therefore were experience-based. The novelty here was to ask participants to predict their performance in both self-performed task and verbal task conditions before they actually experienced the task, therefore exploring participants' general knowledge about the enactment effect. To determine whether learning the material might be associated with metacognitive predictions, we had children make global JOLs both before learning and after learning. In line with past research by Farrant, Boucher, and Blades (1999), who found children with ASD to have spared declarative meta-knowledge of different task variables that affect memory, we hypothesized that both groups should be able to predict the enactment effect and their JOLs should increase at post-learning prediction. Any changes in pre- to post-learning global JOLs would suggest that children in our study monitor online their performance. Also, any differences in children's predictions between conditions would show that they are *sensitive* to the material involved in the task.

In summary, the current study uses global JOLs in a specific memory for action task in order to compare metamemory in autism and typically developing children (controls). While we predicted that children with ASD would be less accurate than controls in metacognitive accuracy, we expected them to become more accurate after experiencing the task (at post-learning prediction). We also expected both groups' accuracy to increase with age. In line with past research, we also expected both groups to show spared metacognitive knowledge of the enactment effect.

2. Method

2.1. Participants

Twenty typically developing children (16 males) and 20 children with ASD (17 males) with similar ages and levels of IQ (as measured by Wechsler Abbreviated Scale of Intelligence) participated in the study (see Table 1). The controls and ASD participants had no known medical or psychological conditions as reported by their parents. The ASD participants were recruited from regional parents' associations and controls from mainstream schools. The study had ethical approval from the University of Leeds Ethical Committee and parental consent was sought prior the study. All children met the Diagnostic and Statistical Manual of Mental Disorders IV-TR (American Psychiatric Association, 1994) autism spectrum criteria which was established by a team of professionals. That is, children had to display substantial difficulties in social interactions, verbal and non-verbal communication as well as limited imagination and rigid thought processes. The recruitment of participants and the testing was carried out by the first author for the purposes of this and other empirical studies.

2.2. Materials and procedure

The procedures were similar to those used by Summers and Craik (1994), but instead of action sentences, action words were used. Ten simple action words such as *spray, kick, wave*, displayed on laminated cards were used for the self-performed task and a set of different 10 action words was used for the verbal task. The two conditions were counterbalanced, and words were presented in a randomized order for each participant. For half of the participants the experiment commenced with the self-performed task where they were given a practice trial with an example word and explained that they would see 10 action words which they would have to enact and remember. Then following the procedures previously used by Moulin et al. (2000), participants were asked to make the pre-learning global JOL by being asked: *How many words out of ten do you think you will be able to remember?* Thus, in the self-performed task the experimenter read aloud and showed children 10 action words one at a time (for 5 s), which they had to enact. After seeing the

Table 1
Participants' characteristics.

	ASD group $n = 20$	Controls $n = 20$	*t-test*
Age (years) M (SD)	11.70 (2.03)	11.05 (2.06)	t (38) = -1, p = .32, d = -.32.
Age range	7–14	9–14	
Full-FSIQ M (SD)	107.45 (14.99)	111.05 (13.31)	t (38) = .80, p = .43, d = .25

Note. FSIQ-Full Scale Intelligence Quotient; **M-mean; SD: Standard Deviation.**

last word, they were asked to make their post-learning global JOL by being asked: *Having seen and heard the words, how many out of ten do you think you will remember*? Free verbal recall followed after a two-minute distracter task (looking at a magazine). After a 10-minute break, the verbal task followed with an identical procedure, including practice trial with no enactment. For the other half of the participants, the experiment started with the verbal task first.

2.3. Memory and metamemory measures

Memory. Free recall was calculated as the number of correctly recalled words in each condition.

Knowledge about task characteristics. Knowledge, here, refers to participants' awareness about different features of the task that might affect performance. In our study higher JOLs for conditions such as self-performed task would indicate awareness of the enactment effect. Thus, in the present study knowledge about task characteristics were measured with the global JOL magnitude.

Calibration. The global JOL magnitude also provided us with information on calibration, which is a way of measuring metacognitive knowledge about children's own memory performance. Calibration helps us to understand whether children over- or underestimate their memory performance by contrasting the magnitude of JOLs with the magnitude of recall scores.

Accuracy. The accuracy was calculated using the method previously used by Hertzog, Saylor, Fleece, and Dixon (1994) called the non-directional discrepancy. Accuracy is calculated as the unsigned difference between the memory score and the metacognitive judgment. For example, the unsigned difference between a recall of 5 words and a global JOL of 9 would be 4. Likewise, the unsigned difference of a recall of 8 and a global JOL of 4 would also be 4. Thus, the higher the score the poorer the accuracy.

3. Results

3.1. Analysis and statistical tools

We examined the group differences in each condition and on pre- and post-learning predictions using ANOVA and significant interactions were explored using t-tests. All the results were also followed up with Bayesian Factor (BF) calculation with JASP Team (2020) where a BF $_{10}$ greater than 1 indicates increasing evidence for the H_a hypothesis over a H_0 (where BF_{10} of 3 or more is substantial evidence, Jeffreys, 1961) and values less than 1 indicate increasing evidence for the null over alternative hypothesis (here BF_{10} of 0.33 or less is substantial evidence (Jeffreys, 1961). This Bayesian analysis was of particular interest when examining the equivalence between the two groups. Data are available on the Open Science Framework (OSF) https://osf.io/2akus/?view_only=ffea36fb25c0415992a4e8f573048632.

3.2. Memory performance: Enactment vs. Verbal task

The descriptive memory and metamemory variables as well as some inferential statistics and Bayes Factors are displayed in Table 2.

We first ran a 2 (group: ASD vs controls) x 2 (condition: self-performed vs verbal task) ANOVA on recall which revealed no main effect of group (F (1, 38) = .004, p = 0.95, η^2_p = 0.0001), but showed a significant effect of condition with a large effect size (F (1, 38) = 36.81, p < 0.001, η^2_p = 0.49) where the recall in the self-performed task was greater than in the verbal task. No significant interaction was found (F (1, 38) = 1.26, p = 0.27, η^2_p = .03). The main effect of group and the group and condition interaction had BF_{10} values of less than 0.33, indicating genuine null findings rather than having noisy data. Bayes Factors for the main effect of condition equaled 1.

3.3. Knowledge about task characteristics and calibration: global JOL magnitude

When looking at descriptive statistics for the mean magnitude of JOLs, we note that both groups underestimated their performance in the self-performed task condition and overestimated it in the verbal task condition. A 2 (group) x 2 (pre/post-learning prediction) x 2 (self-performed versus verbal task) ANOVA on global JOL magnitude revealed no main effect of group (F (1, 38) = .18, p = .68, η^2_p = .005), no main effect of condition, (F (1, 38) = .75, p = .39, η^2_p = 0.02) and no two-way interaction (F (1, 38) = .29, p = 0.60, η^2_p = 0.008). Further, there was no main pre/post learning effect (F (1, 38) = 2.31, p = 0.14, η^2_p = 0.06), and no significant interaction

Table 2
Descriptive and inferential statistics for recall, Global Judgment-of-learning (global JOL) magnitude (out of 10) and global JOL accuracy for the subject-performed task and verbal task in the group with Autism Spectrum Disorder (ASD) and controls.

Subject-performed task						Verbal Task				
	Magnitude			Accuracy		Magnitude			Accuracy	
	Pre-JOL	Post-JOL	recall	Pre-JOL	Post-JOL	Pre-JOL	Post-JOL	recall	Pre-JOL	Post-JOL
ASD M (SD)	5.45 (2.72)	5.75 (2.21)	6.35 (1.95)	3.10 (2.45)	2.30 (1.63)	6.20 (1.85)	5.85 (1.66)	3.95 (1.88)	2.55 (2.42)	2.10 (2.32)
Controls M (SD)	5.70 (1.30)	5.50 (1.32)	5.95 (1.39)	1.25 (.97)	1.55 (.89)	6.10 (1.68)	5.30 (1.22)	4.30 (1.08)	2.10 (1.59)	1.50 (1)

Note. JOL-judgment of learning; M-mean; SD: Standard Deviatio.

between group and pre/post learning predictions (F (1, 38) = 1.90, p = 0.18, η^2_p = 0.05). Also, neither the interaction between condition and pre/post learning predictions (F (1, 38) = 1,72, p = 0.20, η^2_p = 0.04), nor the three-way interactions were significant (F (1, 38) = .003, p = 0.96, η^2_p = 7.239e-5). Since no one comparison yielded a significant difference, we further examined these data with Bayes Factors, calculated using JASP Team (2020). All the main effects had BF_{10} values of less than 0.33 suggesting genuine null findings between groups or conditions, rather than having equivocal or noisy data. Thus, children in both groups show the same magnitude of JOLs for verbal and self-performed task at both, pre- and post-learning predictions.

While the JOL magnitude can inform us about whether or not participants over- or underestimate their performance, the magnitude analysis is prone to regression towards the mean. That is, although the mean values show no difference, there may have been some shift. Thus, a more appropriate analysis of how the predictions relate to performance in a non-directional manner (i.e., global JOLs accuracy) was considered.

3.4. Metacognitive accuracy: global JOLs

A 2 (group) x 2 (condition) x 2 (pre/post) ANOVA on non-directional discrepancies revealed a main effect of group with a medium to large effect size (F (1, 38) = 5.59, $p < 0.05$, η^2_p = 0.13), where the ASD group was less accurate compared to controls, although the BF_{10} indicated that our data is insensitive to support neither H_a, nor H_0 in the full interaction model. No main effect of condition (F (1, 38) = .002, p = 0.97, η^2_p = 3.950e-5), and no significant interaction between group and condition was found (F (1, 38) = 1.44, p = 0.24, η^2_p = 0.04). No significant differences were seen between the pre- to post-learning prediction accuracy (F (1, 38) = 3.57, p = 0.07, η^2_p = 0.09). These null main effects of condition and pre- post-learning predictions had BF_{10} values of less than 0.33. No significant interaction was found between pre/post and group (F (1, 38) = 1.34, p = .25, η^2_p = 0.03) and condition (F (1, 38) = 1.04, p = .31, η^2_{p}. = .03) and BF_{10} values here were also less than 0.33. There was a significant three-way interaction with a medium to large effect size (F (1, 38) = 5.38, $p < 0.05$, η^2_p = 0.12). Independent sample t-tests revealed that there was a group difference on prediction accuracy only in pre-learning prediction and only in the self-performed task (t (38) = -3.14, $p <$ .05, d = -0.99, BF_{10} = 12.05) whereby children with ASD were less accurate than typically developing children. This result yielded a large effect size and the data provided very strong evidence for that difference as measured by BF_{10}. No group difference was found on the post-learning prediction accuracy in the self-performed task (t (38) = -1.81, p = .08, d = -0.57, BF_{10} = 1.11). For the verbal task, groups did not differ on pre- (t (38) = -0.70, p = 0.49, d = -0.22, BF_{10} = .37) or post-learning prediction accuracy (t (38) = -1.06, p = 0.29, d = -0.34, BF_{10} = .48).

We also used paired sample t-tests to examine metacognitive monitoring (pre- to post-learning JOL change in accuracy) in each group. Although both control (t (19) = 2.35, p = .03, d = .53, BF_{10} = 2.09) and ASD groups (t (19) = 2.02, p = .06, d = .45, BF10 = 1.23) became more accurate at post-learning predictions in the verbal task, the difference from pre- to post-learning global JOL in the ASD group tended towards significance only. The result for the ASD group yielded a small to medium effect size and BF_{10} indicated strong support for this difference. In controls, a moderate effect size was obtained, and the data provided strong evidence for that difference, as measured by BF_{10}. No difference between pre- to post-learning prediction accuracy was evident in the self-performed task (ASD: t (19) = 1.37, p = .19, d = .31, BF10 = .52; controls: t (19) = -1.83, p = .08, d = -0.41, BF_{10} = .94).

3.5. Age and metacognitive accuracy

We ran correlations for each group between age and non-directional discrepancy and found no significant correlations for controls in the self-performed task at pre-learning global JOLs (r = -0.007, p = .98) and at post-learning global JOLs (r = -0.33, p = .15), as well as no significant correlation in the verbal task at pre-learning global JOLs (r = -0.23, p = .34) and at post-learning global JOLs (r = -0.22, p = .36). For the ASD group no significant correlation between age and accuracy was found in the self-performed task pre-learning global JOLs (r = -0.08, p = .74). However, a tendency towards a significant correlation was found in the ASD group on post-learning global JOLs in the self-performed task (r = -0.39, p = .09). Interestingly, the correlation with age was significant in the verbal task for both pre-learning global JOLs (r = -0.61, $p < 0.05$) and at post-learning global JOLs (r = -0.61, $p < 0.05$).

4. Discussion

We examined memory and metamemory for actions in children with autism using global metacognitive judgements made before and after completing a task. As predicted, action memory performance in children with autism was comparable to controls and both groups showed the typical enactment effect. Contrary to what we expected, neither group was aware of the mnemonic value of this effect. In terms of knowledge about their own memory performance, as predicted, we found some impairment in metacognitive accuracy in children with ASD. In particular, we found they were less accurate in their pre-learning predictions. However, performance was comparable in both groups on metacognitive monitoring, defined as the shift between pre-to-post accuracy.

As predicted, no group differences in our *simple* free verbal recall task were found which possibly indicates difficulties in ASD only in tasks that exceed their processing capacity (see Williams, Goldstein, & Minshew, 2006) - a finding that is specifically interesting for classroom instruction. As in our previous study (Wojcik et al., 2011), memory performance was facilitated by enactment in both groups, demonstrating that children with autism were able to use the self-performed task's rich multi-sensory representation to improve their memory performance. Therefore, educators could try to promote active involvement of children with ASD, by encouraging the enactment of the to-be-learned material.

The novelty of our study was to examine children's metacognitive knowledge about the enactment effect. Contrary to our previous findings (Wojcik et al.'s, 2011) and contrary to our predictions, we found that neither of the groups predicted the benefit of the self-performed task learning condition with a global JOL procedure. This could be due to the fact that, while in our past study we used judgements after recall, in the present study participants were tested after study but before recall and so could not use monitoring from their recall performance to base their post-learning JOLs on. Thus, it seems that, at least for action word learning, children need to have feedback from their performance to become aware of the benefitial effect of the self-performed task on memory.

With regards to children's knowledge about their own memory function, when looking at JOL magnitude, we found that both groups underestimated their performance in the self-performed task and overestimated it in the verbal task. This is contrary to past research which indicated that children with autism tended to be more positively biased in their self-perceptions which led them to overestimate their performance (Furlano et al., 2015; Furlano et al., 2019). Interestingly, both groups underestimated their performance in a task that in fact improved their memory for words. This pattern of results, however, is in line with research that shows that learners are more likely to underestimate their performance on an easier task (self-performed task) and overestimate it in a task that is more difficult (verbal task) (e.g., Moore & Healy, 2008).

Knowledge about memory function was further looked at through the accuracy of global JOLs as measured by non-directional discrepancies. We found that participants with ASD were, overall, less accurate than controls in their global JOL predictions, with moderate inaccuracy in the prediction for the self-performed task. Further analysis revealed that this difficulty was not related to age in the control group. However, in the ASD group we found that younger children were less accurate in their predictions in both pre- and post-task prediction than controls, but only on the more difficult verbal task. Also, in the post-learning prediction of the self-performed task we found a tendency towards a significant negative correlation between age and metacognitive accuracy in this clinical group. Further research, with larger cohorts and more complex tasks, could help to establish the robustness of these developmental trends in global judgements for both children with and without ASD.

We also investigated metacognitive monitoring, which is shown by the shift towards greater accuracy for post-learning predictions. Unlike in Furlano et al.'s (2015; 2019) study, children with and without ASD became more accurate in their post-learning predictions in the verbal task. We suggest that a better understanding of the specificity of metacognitive deficits in ASD and whether or not it is a general or a specific deficit, could be achieved via multi-trial designs using different tasks (e.g., Moulin et al., 2000).

In the light of previous research, we argue that the status of metamemory functioning in autism depends on when the metacognitive judgements are made (before or after experiencing the task), how difficult the task is (simple or complex recall/recognition task), and the type of cues a given judgement relies on. That is, when children with autism have the chance to experience the task, as was the case in the item-by-item JOLs (Wojcik et al., 2014), in global confidence judgements (Wojcik et al., 2011) or in post-learning global JOLs in the present study, their metacognition is spared. However, experiencing the task has not always been effective in aiding the metacognitive accuracy of individuals with ASD, as was the case for item-by-item confidence judgements (e.g., Williams et al., 2018) or for global predictions in academic tasks (e.g., Furlano et al., 2015). Furlano and Kelly (2019) demonstrated that accuracy of global predictions could be improved in ASD when feedback about the correctness/incorrectness of their answers was explicit. Thus, the difficulty seems to emerge only for predicting upcoming/prospective performance (in the self-performed task only), where individuals with ASD have no access to task cues or when no overt feedback from the performance is given. Interestingly, groups were comparable on global JOL calibration, which given the lack of a group difference on recall, is metacognitively appropriate.

4.1. Conclusions, limitations and future directions

The pattern of strengths and weaknesses in metamemory ability should be taken into account when designing metacognitive training in ASD. However, our results are preliminary, rather than conclusive given that our sample size was small, limiting our ability to confidently interpret our results, with small to medium effects sizes *in our key findings*. Supplementary Bayesian analyses help somewhat mitigate this problem of a low sample size, where clear null effects in the magnitude of global JOLs between the two groups were observed. In our study, we can be confident that there is no systematic difference in how many words children with ASD and a comparison group predicted they would recall. In the context of little or no difference in the actual recall between the two groups (less than half a word's difference in the recall scores, again supported by a Bayesian analysis), this is perhaps the easiest way to interpret the pattern of findings. That is, children with ASD made predictions that are generally no different from a comparison group, and their performance was likewise, no different. If there is a score which is strikingly different between the two groups, it is the accuracy of predictions made before completing the self-performed task, but once the task has been completed, there is little evidence for a difference between groups in their accuracy. What limits our conclusions here, however, is the small number of observations in our trial (i.e., a single list of 10 action words). Therefore, increasing the number of observations could help improve the robustness of the current results, since we might posit that there was a slight inaccuracy in the global JOLs in general in ASD. Finally, future research should examine metacognitive monitoring using a variety of ecologically valid tasks and tasks with different levels of complexity. We would expect that initial memory deficits on complex, multi-trial tasks in ASD to decrease with increasing global JOLs accuracy over trials.

Data availability

As stated in the text, the data is available at Open Science Framework under this link: https://osf.io/2akus/?view_only=ffea36fb25c0415992a4e8f573048632

The data that has been used is confidential.

Author agreement

All authors can certify to have seen and approved the final version of the manuscript being submitted. They warrant that the article is the authors' original work, has not received prior publication and is not under consideration for publication elsewhere.

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CRediT authorship contribution statement

Dominika Zofia Wojcik: Conceptualization, Formal analysis, Data curation, Investigation, Methodology, Project administration, Investigation, Writing - original draft, Writing - review & editing. **Christopher J.A. Moulin:** Conceptualization, Formal analysis, Methodology, Investigation, Writing - original draft, Writing - review & editing, Supervision. **C. Souchay:** Conceptualization, Methodology, Project administration, Investigation, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

Authors have no competing interests to declare.

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