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Is visual metacognition associated with autistic traits? A regression analysis shows no link between visual metacognition and Autism-Spectrum Quotient scores

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A R T I C L E I N F O

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A B S T R A C T

Metacognition —the human ability to recognize correct decisions— is a key cognitive process linked to learning and development. Several recent studies investigated the relationship between metacognition and autism. However, the evidence is still inconsistent. While some studies reported autistic people having lower levels of metacognitive sensitivity, others did not. Leveraging the fact that autistic traits are present in the general population, our study investigated the relationship between visual metacognition and autistic traits in a sample of 360 neurotypical participants. We measured metacognition as the correspondence between confidence and accuracy in a visual two alternative forced choice task. Autistic-traits were assessed through the Autism-spectrum Quotient (AQ) score. A regression analysis revealed no statistically significant association between autistic traits and metacognition or confidence. Furthermore, we found no link between AQ sub-scales and metacognition. We do not find support for the hypothesis that autistic traits are associated with metacognition in the general population.

1. Introduction

Autism is a neurodevelopmental condition that can make social interaction, broad interests, and flexible thinking challenging (American Psychiatric Association, 2013; Baron-Cohen, 1991; Capps et al., 1992; Davies et al., 1994; Hobson et al., 1988; Kanner & Lesser, 1958; Yirmiya et al., 1992). Autistic people may struggle to understand the emotions and thoughts of others (Yirmiya et al., 1998), and several studies suggest they may also have difficulty comprehending their own thoughts (Carpenter et al., 2019b; Grainger et al., 2016a; Nicholson et al., 2019, 2020; Wilkinson et al., 2010; Williams et al., 2018). Specifically, research has found that autistic individuals often exhibit altered metacognition (Carpenter et al., 2019b; Grainger et al., 2016a; Nicholson et al., 2019, 2020;

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Wilkinson et al., 2010; Williams et al., 2018) - the ability to reflect on one's own thinking and behavior (Carpenter et al., 2019bFlavell, 1979; Fleming et al., 2012; Metcalfe & Shimamura, 1994; Morales et al., 2018; Nelson & Narens, 1990; Fleming, 2021). Given the importance of metacognition for learning and development (Fleming, 2021; Hembacher & Ghetti, 2014; Roebers, 2017; Fleur et al., 2021), understanding the nature of this difficulty is crucial. However, the evidence on the issue remains mixed (Carpenter et al., 2019b; Grainger et al., 2016a, 2016b; Maras et al., 2017, 2020; Nicholson et al., 2019, 2020; van der Plas et al., 2021; Williams et al., 2018).

According to the dimensional approach, autism is best understood as existing on a spectrum, which includes individuals in the general population exhibiting varying degrees of autistic traits (Barttfeld et al., 2013; Constantino et al., 2003; Constantino & Todd, 2005; Lau et al., 2013). This approach has led to the creation of behavioral measures for assessing autism traits in the general population and its use in studying autism (Baron-Cohen et al., 2001). The dimensional approach may reveal relationships that are obscured by binary diagnostic categories.

One such relationship might pertain to metacognition. As the presence, function, and severity of autistic traits vary among individuals, not all autistic people may experience the same type of metacognitive difficulties. Recent research found that individuals who struggle with social interaction and communication exhibit worse metacognition than those who do not (Van der Plas et al., 2021). If confirmed, this result could have important practical and theoretical implications. Interventions aimed at improving metacognition could be targeted to this specific subpopulation. Additionally, evidence suggests that metacognitive ability can be trained (Carpenter et al., 2019a; Fleur et al., 2021; Taouki et al., 2022; Aghotor et al., 2010). Thus, if some autistic individuals have impaired metacognition while others do not, assessments and interventions could be tailored to only the affected population, saving time and resources for those whose metacognition is not impaired.

The findings would also have important theoretical implications, as they would fit into the ongoing debate about the relationship between metacognition and theory of mind or mindreading (Nicholson et al., 2019, 2020; Grainger et al., 2016a; Carruthers, 2009; Goldman, 2006; Nichols & Stich, 2003). Theory of mind is typically defined as the ability to understand and represent the mental states of others (Nicholson et al., 2019, 2020; Grainger et al., 2016a). Some researchers propose that metacognition and theory of mind rely on the same underlying mechanism, known as the "one system account" (Carruthers, 2009). Others argue that these are two separate abilities achieved through different cognitive mechanisms, known as the "two system account" (Nichols & Stich, 2003). A third perspective claims that theory of mind depends on our introspective access to our own mental states, and that metacognition precedes theory of mind (Goldman, 2006).

It is important to note that there is a significant body of evidence indicating that theory of mind is impaired in autistic people (Nicholson et al., 2019, 2020; Grainger et al., 2016a; Brunsdon & Happé, 2014; although see Milton (2012) for another perspective regarding this issue). Therefore, if metacognition is consistently found to be intact in autistic people, it would provide strong evidence that metacognition and theory of mind are separate cognitive mechanisms (Nicholson et al., 2019, 2020; Grainger et al., 2016a). Despite numerous studies investigating the relationship between autism and metacognition, the topic remains widely debated (Carpenter et al., 2019b; Grainger et al., 2016a, 2016b; Maras et al., 2017, 2020; Nicholson et al., 2019, 2020; Sawyer et al., 2014; van der Plas et al., 2021; Wilkinson et al., 2010; Williams et al., 2018; Wojcik et al., 2011).

Interestingly, some studies support the idea that autistic people have an altered metacognition (Grainger et al., 2016a; Nicholson et al., 2019, 2020; van der Plas et al., 2021; Wilkinson et al., 2010). For example, Grainger et al. (2016a) compared a group of autistic children with a control group and used judgment of confidence after a study phase. They found that the autistic group had decreased metacognitive monitoring accuracy. Nicholson et al. (2019) examined both implicit metacognition (assessing the accuracy of strategic behavioral reactions without a verbal response) and explicit metacognition (with a verbal response). They found no differences in implicit metacognition but did observe differences in the explicit metacognition. Nicholson et al. (2020) also found that autistic children/adolescents had decreased explicit metacognition compared to the control group, but found no difference in implicit metacognition.

Van der Plas et al. (2021) found that autistic traits evaluated using the RAADS-14 (Eriksson et al., 2013) were not significantly related to metacognitive sensitivity in a sample of participants from the general population. However, they found that participants who reported difficulties with social interaction in everyday life had worse metacognitive sensitivity than those who did not. Additionally, they compared an autistic group with a group of participants with low autistic traits and found evidence supporting the view that metacognition is altered in the autistic group. Interestingly, their results also suggest that metacognition sensitivity is related specifically to social autistic traits (Van der Plas et al., 2021). Wilkinson et al. (2010) performed a memory awareness test during a face recognition task, and their results suggested that adults and children on the autistic spectrum have altered metacognition compared to a control group.

Several other studies found no differences between the autistic and control groups (Grainger et al., 2016b; Maras et al., 2017, 2020; Sawyer et al., 2014; Wojcik et al., 2011, 2014). For example, Grainger et al. (2016b) performed two experiments using a judgment of learning task (JOL), comparing adults and adolescents on the spectrum and controls participants. Curiously, they found equal JOL accuracy in both autistic groups. Maras et al. (2017) used a math challenge task to compare the metacognitive monitoring of secondary autistic children to that of controls participants and did not observe any differences between groups. Maras et al. (2020) also found unaltered metacognition monitoring in the autistic group compared to a control group using a memory task. Sawyer et al. (2014) used an emotion recognition task and a general knowledge task to compare autistic individuals with a control group and found no diminished metacognitive monitoring in the autistic group. Wojcik et al. (2011) compared the JOC accuracy of a memory task between autistic children and a control group, and did not observe a significant difference. Similarly, Wojcik et al. (2014) compared two groups of adolescents (autistic and control) using JOL and did not observe any differences.

Some other studies have found mixed results (Carpenter et al., 2019b; Williams et al., 2018). For example, Carpenter et al. (2019b) used a post-decision wandering paradigm with a perceptual task and found a negative association between autistic traits and metacognition in a sample of the general population, although they did not find differences in metacognition between autistic adults and a control group. Williams et al. (2018) performed a general knowledge question task in a sample of the general population and did not observe a significant relationship between autistic traits and JOC. They also compared a control group of children with a group of autistic children and found that the group of autistic children had a lower JOC compared to the control group.

It is important to note that all the studies that have explored the relationship between autism and metacognition present several differences at the methodological level, one of which is the way of understanding metacognition. Metacognition is a rather broad concept that can be quantified in various ways (Fleming & Lau, 2014). One approach to understand metacognition is to divide it into two components: metacognitive sensitivity and metacognitive bias (Fleming & Daw, 2017; Fleming & Lau, 2014). Metacognitive sensitivity is operationally defined as the ability to distinguish between correct and incorrect answers based on the confidence in one's answers (Fleming & Daw, 2017; Fleming & Lau, 2014). Metacognitive bias refers to the overall confidence in one's answers, such as overconfidence or underconfidence. Some metacognition measures allow for the separation of these two components in order to control the influence of one over the other (Fleming & Lau, 2014). Nevertheless, only Nicholson et al. (2020) and Van der Plas et al. (2021) have used a bias-free measure of metacognition. Another important consideration in studying autism is the use of a dimensional approach. Measures such as the Autism Spectrum Quotient (AQ; Baron-Cohen et al., 2001) make it possible to assess autistic traits in the general population. By using such measures in conjunction with online experimental procedures, it is possible to recruit a large number of participants. Lastly, given the diversity of tasks used in the literature to study the link between metacognition and autism, the modality where metacognition is evaluated might also be important. Indeed, it is not yet clear whether metacognition is domain-general or domain-specific (Faivre et al., 2018; Rouault et al., 2018a). If metacognition turns out to be domain-specific, several findings would be hard to compare. For example, only a few studies used a visual perceptual task (Nicholson et al., 2019, 2020; van der Plas et al., 2021; Carpenter et al., 2019b).

The visual domain is of particular interest as it has been observed that autistic individuals perform better than comparison groups in perceptual tasks, excelling at the recognition of details and the ability to find hidden figures (Dakin & Frith, 2005; Pellicano & Burr, 2012; Plaisted et al., 1998). Autistic individuals seem to have a more veridical perception and a weaker influence of expectation (Karvelis et al., 2018). The idea that autistic people perceive the world differently is one of the most intriguing features of autism and might constitute one of its defining features. Some mainstream theories of autism point to a strong relationship between enhanced perception skills and the central disturbances of autism (Dakin & Frith, 2005; Mottron et al., 2006; Pellicano & Burr, 2012; Plaisted et al., 1998). The relatively stronger influence of sensory information could explain hypersensitivity to sensory stimuli and extreme attention to details (Karvelis et al., 2018; Pellicano & Burr, 2012). Furthermore, this could lead to specific prior expectations that do not generalize across situations (Van de Cruys et al., 2014). One might be tempted to think that the enhanced perceptual abilities of autistic individuals suggest that they have a more conscious perceptual mechanism, leading to an enhanced (perceptual) metacognition.

The inconsistencies in the results of previous studies on the relationship between autism and metacognition, and their important theoretical and practical implications, highlight the need for further research to examine the nuances of this relationship (Carpenter et al., 2019b; Grainger et al., 2016a, 2016b; Maras et al., 2017, 2020; Nicholson et al., 2019, 2020; Sawyer et al., 2014; van der Plas et al., 2021; Wilkinson et al., 2010; Williams et al., 2018; Wojcik et al., 2011). In this study, we aim to explore the relationship between metacognitive sensitivity and autistic traits. To test the robustness of our findings, we used two metacognitive measures: the type 2 Receiver Operating Characteristic (ROC) curve (also called AUROC2; Fleming & Lau, 2014) and a mixed logistic regression model (Siedlecka et al., 2016). Both of these measures are bias-free, meaning that they allow separation of metacognitive bias from metacognitive sensitivity. This is important in the light of recent findings that show a negative relationship between autistic traits and confidence (van der Plas et al., 2021). Additionally, we used the *meta*-d' measure, which is also a bias free measure of metacognitive sensitivity, and m-ratio, which measures metacognitive efficacy (see Maniscalco & Lau, 2012; 2014 for a detailed explanation of these two measures). Furthermore, we explore whether metacognitive sensitivity and autistic traits are related in specific ways by using the subscales of the autistic trait test (Social Skill, Attention Switching, Attention to Detail, Communication, and Imagination). Lastly, we investigate the relationship between confidence and autistic traits.

2. Material and methods

2.1. Participants

The final sample consisted of 360 participants of the general population (Age: M = 32.14, SD = 11.06, range = 19–72, 107 males). Participants were recruited using multiple approaches. An invitation to participate in the study was circulated on the authors' corresponding Universities' email distribution lists of volunteers and shared over social media through the authors' lab accounts. Participants met the following criteria: no use of psychotropic medication, no psychiatric diagnosis, and over 18 years of age). From an initial sample of 457 participants, 97 participants were excluded because they met at least one the the following exclusion criteria: 1) reported that they had not performed the experiment seriously or had been interrupted during the task (6 participants); 2) had a performance lower than 60% (2 participants; as in: Van der Plas et al., 2021; Rouault et al., 2018b; Rollwage et al., 2018; Mazor et al., 2021; Mazor et al., 2020; Carpenter et al., 2019a); 3) have pressed the same confidence key more than 85% of trials (25 participants; similar to: Mazor et al., 2020; Van der Plas et al., 2021; Rollwage et al., 2018; Carpenter et al., 2019a; Rouault et al., 2018b); 4) have less than 90 trials after filtering reaction times to allow for robust AUROC2 estimates (29 participants) and 5) had an AUROC2 lower than 1.5 standard deviations from the mean to avoid outliers (27 participants; A cut-off point was also set here). We also excluded participants who did not report a choice of binary male or female gender (8 participants) as they were too few to be accounted for in the regression model controlled by gender. The percentage of excluded participants is consistent with other online studies (Chandler et al., 2014). The sample size was determined a priori to be similar to the sample size in papers investigating metacognition and autistic traits. For example, the sample size of Van der Plas et al. (2021) was 477 participants. The sample size to predict a variable (AUROC2, Confidence mean, meta-d' or m-ratio) with a multiple linear regression of 3 predictors (AQ test, gender and age), assuming a medium

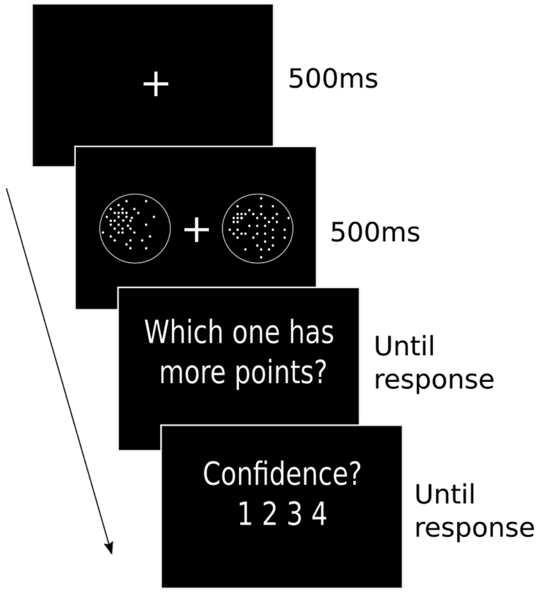

Fig. 1. *Task procedure Note.* The experimental task consisted of a series of trials in which participants were presented with two circles, one on the left and one on the right. They were asked to determine which circle had more dots and indicate their choice by pressing the corresponding arrow key (left or right). Following their decision, participants were prompted to rate their confidence in their choice on a 4-point Likert scale. This sequence of events was repeated for each trial of the task.

effect size (f2 = 0.15), an alpha = 0.05 and a power of 0.8, is 77 participants according to G*Power 3.1.9.7 (Faul et al., 2009). With 7 predictors (the 5 subscales of the AQ, gender and age) the sample size goes to 103 participants. The present study far exceeded that number. See Data Analysis section for more details.

All participants signed an informed consent. The present study was approved by the ethics committee of the Instituto de Investigaciones Psicológicas (CONICET, Córdoba, Argentina).

2.2. Task

The experiment was implemented in JavaScript and managed through JATOS, a platform for online experiments (Lange et al., 2015). Participants were instructed to sit 60 cm away from the screen, minimize distractions, and silence their cellphones and computer notifications. They were also asked to respond to each trial within 3–5 s. During the session, participants completed the AQ (Baron-Cohen et al., 2001) and a dot density task (see Fig. 1). The dot density task consisted of 130 trials in 1 block. Each trial began with a fixation cross, followed by two horizontally aligned circles presented for 500 ms. Participants were asked to indicate which circle had more dots by pressing the left or right arrow key and then indicate their confidence level using a 4-point Likert scale. The radius of the circles was calculated as 0.15 of the browser's window width, while the dots had a radius of 10 pixels. The task difficulty level was controlled through a two-down/one-up staircase procedure, resulting in a theoretical performance of 72% (Prins, 2016). The procedure also controlled the influence of performance on the AUROC2 measure (Fleming & Lau, 2014). On average, participants completed the experimental task in 5 min on average.

2.3. Data analysis.

Data analysis was performed in R (Team, R., 2020). In the dot discrimination task, trials with reaction times (RT) greater than 5000 ms and less than 200 ms were excluded (4.28% discarded). Additionally, in the confidence task, trials with RT greater than 5000 ms were removed (0.07% discarded). The first 20 trials of each participant were also discarded to allow the staircase to stabilize.

Two bias-free methods were employed to measure metacognitive sensitivity: the area under the AUROC2 (Fleming & Lau, 2014) and a mixed logistic regression model (Siedlecka et al., 2016). Additionally, *meta*-d' and M−ratio were used to verify the robustness of the results (Maniscalco & Lau, 2012; 2014; see appendix section, tables from A.1 to H.1). The following paragraphs provide a brief explanation of the procedures used to calculate metacognition using each method, based on data from two fictitious participants: one with poor metacognitive sensitivity (Fig. 2a) and one with relatively high metacognitive sensitivity (Fig. 2b). Fig. 2a illustrates an uninformative confidence distribution, while Fig. 2b displays a highly informative confidence distribution.

The AUROC2 is a non-parametric measure that enables the calculation of a metacognitive sensitivity measure that is independent of metacognitive bias (Fleming & Lau, 2014). This measure assesses the extent to which the confidence rating alone can provide information about the likelihood of a correct response. For each participant, we created a distribution of reported confidence levels for correct and incorrect trials (as shown in Fig. 2a and 2b). Since we used a 4-level confidence scale, three cut-off points were defined. One cut-off point at

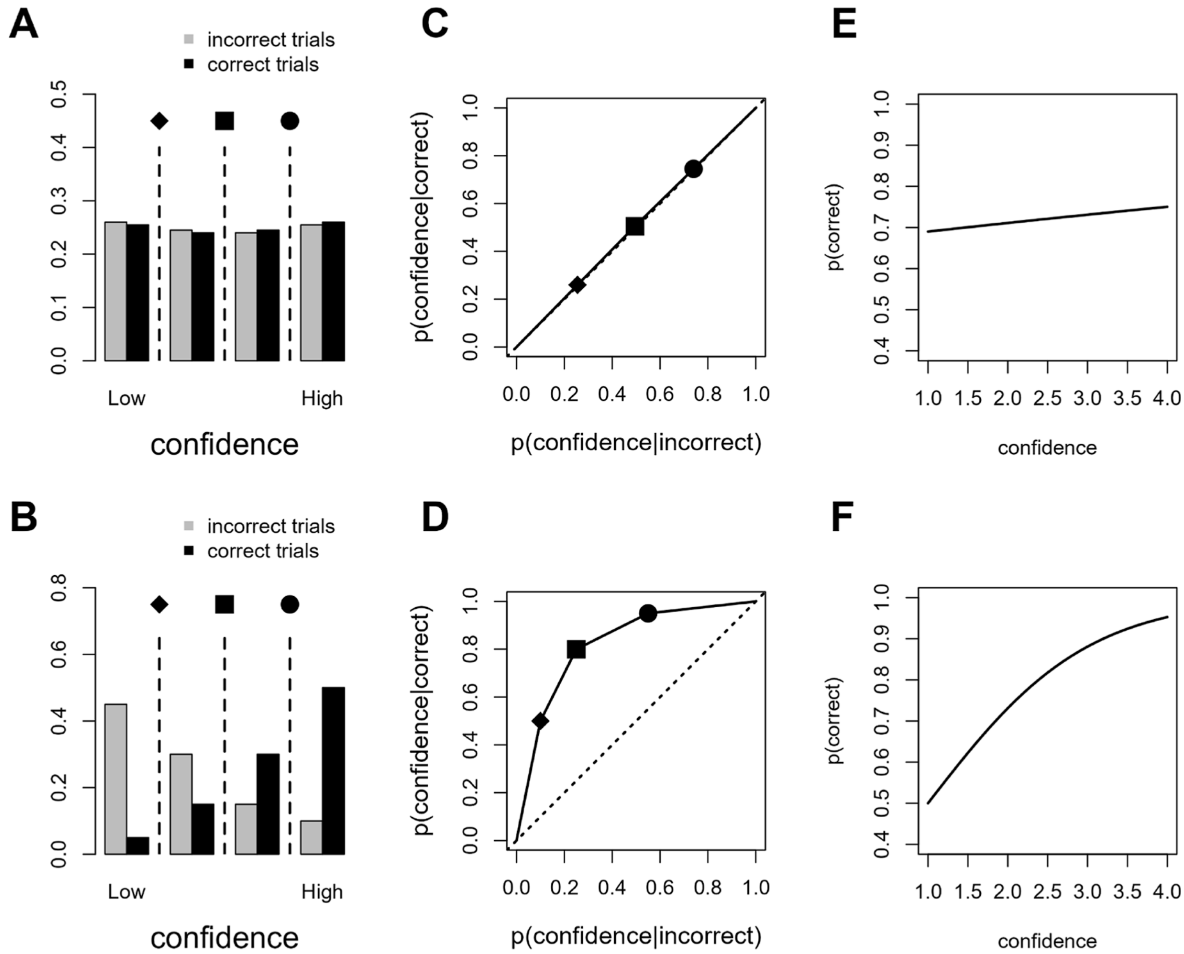

Fig. 2. *Estimation of metacognitive sensitivity using the AUROC2 and logistic regression model of two fictitious participants Note.* The first and second rows depict the performance of a hypothetical participant with low and high metacognitive sensitivity, respectively. The plots labeled A and B illustrate the distribution of confidence levels for correct and incorrect trials. C and D display the area under the receiver operating characteristic curve (AUROC) for each participant. The plots labeled E and F depict the inferred probability of choosing the correct response as a function of confidence level, as determined by a logistic regression model. The slope of the curve in plot F is steeper than that in plot E, indicating that confidence is a more accurate predictor of the probability of getting the answer right in the second case (i.e., higher metacognitive sensitivity).

a time, we calculated three type 2 hit rates (proportion of high confidence trials when the trial was correct) and three type 2 false alarm rates (proportion of high confidence trials when the trial was incorrect). Then, a plot of the inverse cumulative type 2 hit rate versus the inverse cumulative type 2 false alarm rate is the type 2-ROC curve (as shown in Fig. 2c and 2d). Finally, the area under the curve is the AUROC2. Fig. 2c and 2d show the AUROC2 for each fictitious participant; Fig. 2a represents a participant with poor metacognitive sensitivity and Fig. 2b represents a participant with high metacognitive sensitivity. The area under the curve represents metacognitive sensitivity. The greater the area under the curve, the higher the metacognitive sensitivity score (Fleming & Lau, 2014).

After obtaining a measure of metacognition for each participant, we conducted a regression analysis to investigate the relationship between autistic traits and metacognitive sensitivity. The linear model was:

$$\text{AUROC2} = \alpha + \text{AQ score} * \beta_1 + \text{gender} * \beta_2 + \text{age} * \beta_3 + \text{AQ score} * \text{gender} * \beta_4 + \text{AQ score} * \text{age} * \beta_5 + \text{errors},$$

where AUROC2 is the dependent variable and the predictor variables were standardized AQ score, gender, standardized age, and their interactions.

Our second method for measuring metacognition involved fitting a mixed logistic regression model. A logistic regression model is suitable for predicting a binary categorical variable, such as whether the answer was correct or incorrect (Siedlecka et al., 2016). This method has several advantages over the AUROC2 method, such as not relying on theoretical assumptions about the confidence distribution, being less affected by imbalanced numbers of correct and incorrect responses and controlling for inter-subject variability in parameter estimation (Siedlecka et al., 2016, but see: Rausch et al., 2015; Rausch & Zehetleitner, 2017). Fig. 2e and f show the predicted line for each participant (a and b, respectively). The mixed logistic regression model is:

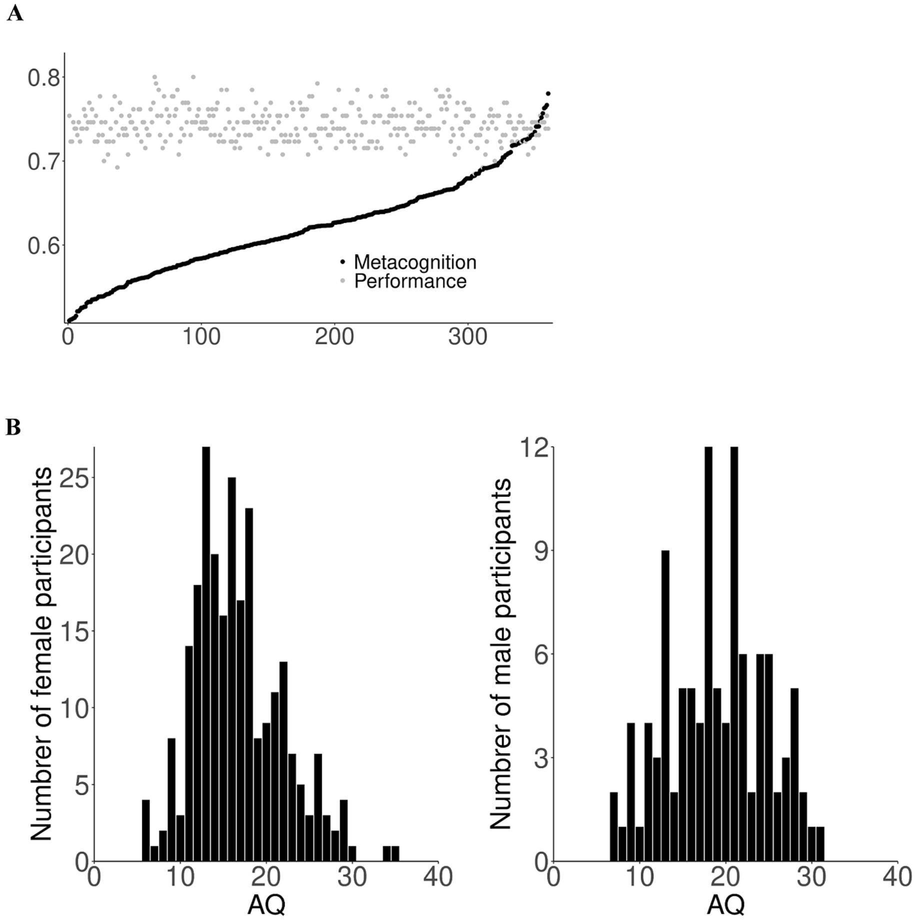

Fig. 3. **A** Metacognitive sensitivity and performance per participant Note. Performance was maintained at a consistent level due to the use of a staircase procedure, while individual differences in metacognition were observed among participants. AQ score for female and male participants.

$$\text{logit}(p) = \alpha + MC * \text{confidence},$$

where the logit(p) is the logarithm of the odds ratio, which is the ratio of the probability of being correct to the probability of being incorrect, and.

$$MC = \beta_0 + \text{AQ score} * \beta_1 + \text{gender} * \beta_2 + \text{age} * \beta_3 + \text{AQ score} * \text{gender} * \beta_4 + \text{AQ score} * \text{age} * \beta_5,$$

The intercept varied among participants and was the only random effect factor. The predictors included the standardized AQ score, gender, standardized age, and the interactions of gender and standardized age with the standardized AQ score, all of which were treated as fixed effects.

To investigate whether metacognitive sensitivity has a specific relationship with autistic traits, another linear regression was conducted, using the standardized AQ subscale scores, gender, and standardized age as predictors and metacognitive sensitivity estimated by the AUROC2 as the dependent variable. The following model was used:

$$\text{AUROC2} = \alpha + \text{social skill score} * \beta_1 + \text{attention switching} * \beta_2 + \text{attention to detail} * \beta_3 + \text{communication} * \beta_4 + \text{imagination} * \beta_5 + \text{gender} * \beta_6 + \text{age} * \beta_7 + \text{errors}.$$

Lastly, the relationship between confidence and AQ was also examined using the following equation:

$$\text{Confidence} = \alpha + \text{AQ score} * \beta_1 + \text{gender} * \beta_2 + \text{age} * \beta_3 + \text{AQ score} * \text{gender} * \beta_4 + \text{AQ score} * \text{age} * \beta_5 + \text{errors}.$$

Where the mean confidence level per participant was the dependent variable, and the standardized AQ, gender, standardized age, and their interactions were the predictor variables.

In addition to the metacognitive sensitivity measures, we also used meta-d’ and M−ratio to assess the robustness of the results

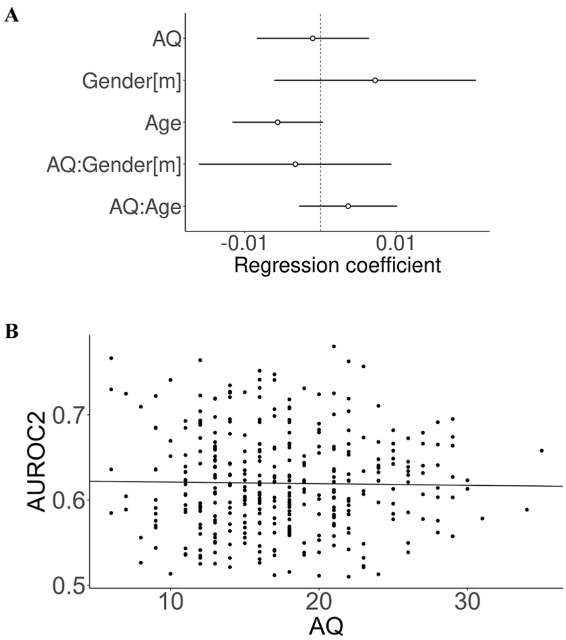

Fig. 4. Linear regression model used to study the relationship between autistic traits and metacognitive sensitivity.

Table 1
The linear regression model results used to study the relationship between autistic traits and metacognitive sensitivity (AUROC2).

	Beta	SE	95% CI	p-value	q-value
Intercept	0.620	0.004	0.613, 0.627	**<0.001**	**<0.001**
AQ.std	−0.001	0.004	−0.008, 0.006	0.787	0.787
Gender[m]	0.007	0.007	−0.006, 0.021	0.287	0.431
Age.std	−0.006	0.003	−0.012, 0	0.063	0.188
AQ.std * Gender[m]	−0.003	0.006	−0.016, 0.009	0.607	0.728
AQ.std * Age.std	0.004	0.003	−0.003, 0.010	0.266	0.431
R2	0.018				
Adjusted R2	0.004				
Power	0.14				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

(Maniscalco & Lau, 2012; 2014; see appendix section, tables from A.1 to H.1). This was done to examine their relationship to the AQ test and AQ subscales. To accomplish this, we employed the same equations used to predict AUROC2, but replaced AUROC2 with *meta-d'* and M−ratio. To determine the power of each analysis, we utilized the R package 'pwr' for all multiple linear regression models (pwr.f2.test function). For the mixed logistic regression model, we utilized the R package 'simr' (powerSim function) with 5000 simulations for each interaction of interest (confidence * AQ score * β_1).

3. Results

As expected, AUROC2 values showed great variation among participants (Fig. 3a). Mean AUROC2 was 0.62 (*SD* = 0.057, range = 0.51–0.78). AQ score also showed expected variability among participants, ranging from 16 to 37 (Fig. 3b). Mean AQ score was 17.38 (*SD* = 5.45, range = 6–35), and was significantly higher for males than for females (females: mean = 16.73, *SD* = 5.20; males: mean = 18.91, *SD* = 5.73; $t(183.51) = -3.386$, *p* less than 0.001) consistent with previous literature (female:15.4; male: 17.8; Baron-Cohen et al., 2001).

The linear regression model used to study the relationship between autistic traits and metacognitive sensitivity (Fig. 4a and 4b; Table 1) showed that the standardized AQ score and its interactions with gender and standardized age were non-significant predictors of AUROC2.

To expand on our findings, we also conducted a mixed logistic regression model (Fig. 5a; Table 2). The intercept estimates the average accuracy on the logit scale for the lowest confidence rating. We observed that confidence significantly predicted accuracy. However, its interactions with standardized AQ, with standardized AQ and gender, and with standardized AQ and standardized age were not significant predictors of accuracy.

To further explore the relationship between autistic traits and metacognitive sensitivity, another linear regression model was conducted, using the AQ subscales as predictors of AUROC2. The linear regression model (Fig. 6; Table 3) showed that the standardized social skill score, standardized attention switching score, standardized attention to detail score, standardized communication score,

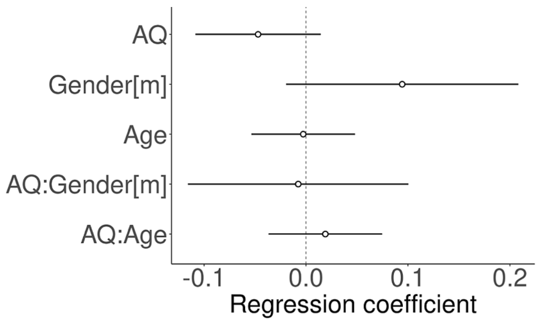

Fig. 5. The mixed logistic regression model result to study of the relationship between autistic traits and metacognitive sensitivity.

Table 2
The mixed logistic regression model results to study of the relationship between autistic traits and metacognitive sensitivity.

	log(OR)	SE	95% CI	p-value	q-value
Intercept	0.286	0.028	0.232, 0.341	**<0.001**	**<0.001**
Confidence.norm	1.426	0.051	1.327, 1.525	**<0.001**	**<0.001**
Confidence.norm * AQ.std	−0.047	0.031	−0.108, 0.014	0.134	0.234
Confidence.norm * Gender[m]	0.094	0.058	−0.020, 0.208	0.104	0.234
Confidence.norm * Age.std	−0.003	0.026	−0.054, 0.048	0.916	0.916
Confidence.norm * AQ.std * Gender[m]	−0.008	0.055	−0.116, 0.100	0.889	0.916
Confidence.norm * AQ.std * Age.std	0.019	0.028	−0.037, 0.075	0.505	0.707
Subjects SE(intercept)	0.201				
Deviance	43,050				
Power for Confidence.norm * AQ.std	0.32				

Note. OR = Odds Ratio; SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male; Statistical significance;.norm = normalized;.std = Standardized.

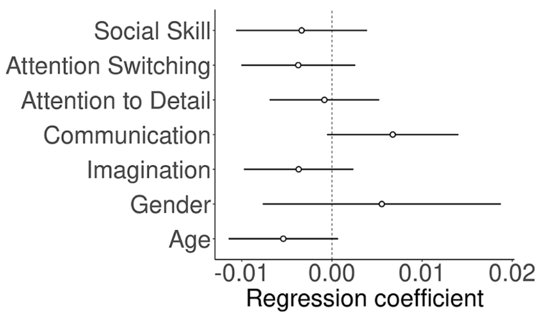

Fig. 6. The linear regression model result used to study the relationship between the subscales of the AQ and metacognitive sensitivity.

Table 3
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive sensitivity (AUROC2).

	Beta	SE	95% CI	p-value	q-value
Intercept	0.620	0.004	0.613, 0.627	**<0.001**	**<0.001**
Social Skill.std	−0.003	0.004	−0.011, 0.004	0.362	0.469
Attention Switching.std	−0.004	0.003	−0.010, 0.003	0.246	0.393
Attention to Detail.std	−0.001	0.003	−0.007, 0.005	0.787	0.787
Communication.std	0.007	0.004	−0.001, 0.014	0.069	0.217
Imagination.std	−0.004	0.003	−0.010, 0.002	0.232	0.393
Gender[m]	0.006	0.007	−0.008, 0.019	0.410	0.469
Age.std	−0.005	0.003	−0.011, 0.001	0.082	0.217
R2	0.028				
Adjusted R2	0.009				
Power	0.201				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

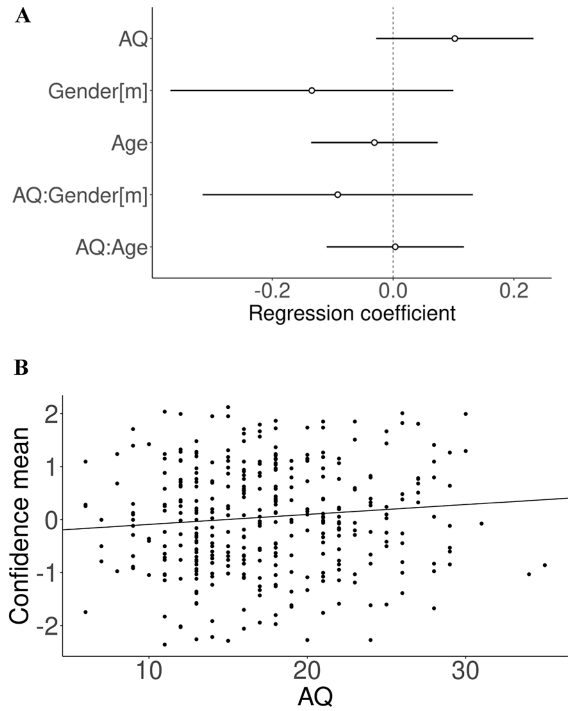

Fig. 7. A The linear regression model result used to study the relationship between autistic traits and confidence Predicted values for confidence mean.

Table 4
The linear regression model results used to study the relationship between autistic traits and confidence.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.048	0.064	−0.077, 0.173	0.452	0.674
AQ.std	0.102	0.066	−0.028, 0.232	0.124	0.674
Gender[m]	−0.134	0.119	−0.369, 0.100	0.259	0.674
Age.std	−0.031	0.053	−0.136, 0.074	0.562	0.674
AQ.std * Gender[m]	−0.092	0.114	−0.315, 0.132	0.421	0.674
AQ.std * Age.std	0.004	0.058	−0.110, 0.117	0.951	0.951
R2	0.011				
Adjusted R2	−0.003				
Power	0.346				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized.

and standardized imagination were non-significant predictors when AUROC2 was the dependent variable.

Lastly, we examined the relationship between confidence and standardized AQ (Fig. 7; Table 4). It was observed that the standardized AQ score, and its interactions with gender and standardized age were non-significant predictors of the mean confidence level per participant.

To evaluate the robustness of our results, we conducted the same four regression analyses without controlling for age and gender. Overall, the results were consistent with those obtained when controlling for age and gender (see Appendix tables I.1 to L.1). To further test the robustness, we also conducted the analysis using *meta*-d' and M−ratio, which also yielded no significant results (see Appendix section, tables A.1 to H.1). To further verify the robustness of the negative results, we repeated the analyses without removing any participants or trials based on exclusion criteria (only removing trials where participants took more than 20 s to respond). The results were virtually the same (see Appendix tables M.1 to T.1) with the exception of the imagination subscale of AQ which turned out to be significant (β = -0.008; SD = 0.003; p = 0.046; see Appendix table O.1). However, this result did not replicate when the variable being predicted was meta-d' as a measure of metacognitive sensitivity (β = -0.062; SD = 0.032; p = 0.146; see Appendix section, table R.1).

4. Discussion

The main objective of the present study was to explore the relationship between metacognition and autistic traits. Our results did not show a significant relationship between the AQ score and metacognition with none of the three methods we implemented, even after controlling for gender and age. This is consistent with some previous studies (Carpenter et al., 2019b; Grainger et al., 2016b;

Maras et al., 2017, 2020; Sawyer et al., 2014; Williams et al., 2018; Wojcik et al., 2011, 2014) but is not aligned with other works showing altered metacognition in autistic people (Carpenter et al., 2019b; Grainger et al., 2016a; Nicholson et al., 2019, 2020; Wilkinson et al., 2010; Williams et al., 2018).

A possible explanation for these inconsistencies is that the relationship between autism and metacognition may be specific and complex, and certain characteristics of the sample may obscure the interaction between the two. For example, if metacognition is impaired only in a specific subpopulation of autistic people, and this subpopulation is not adequately represented in the sample, it is likely that some studies will find altered metacognition in autistic people while others will not. Additionally, previous studies such as Van der Plas et al. (2021), have suggested that only certain traits of autism, such as difficulty in social communication, may be related to metacognition. In order to further explore this relationship, we also looked at each subscale of the AQ as a predictor of metacognitive sensitivity, but again found no significant relationships.

Another possibility is that the inconsistent results across studies are due to the use of different measures of autistic traits. We used the AQ (Baron-Cohen et al., 2001) while other studies have used the RAADS-14 (Eriksson et al., 2013). While the AQ is designed to measure the degree to which adults have characteristics associated with the autism spectrum, the RAADS-14 is primarily used for the diagnostic process of autism (Eriksson et al., 2013). In addition, these tests present different subscales (AQ: Social Skill, Attention Switching, Attention to Detail, Communication, Imagination; RAADS-14: Circumscribed Interests; Language; Social Relatedness; Sensory Motor). We suspect that the inconsistencies in the literature are not solely due to the choice of measure, as both Carpenter et al. (2019b) and Williams et al. (2018) used the AQ yet did not find the same results. Additionally, studies that have compared two groups (autism vs. control) also present inconsistent results, with some showing evidence of metacognitive alteration in autistic individuals (Grainger et al., 2016a; Nicholson et al., 2019, 2020; van der Plas et al., 2021; Wilkinson et al., 2010) and others not observing any difference (Grainger et al., 2016b; Maras et al., 2017, 2020; Sawyer et al., 2014; Wojcik et al., 2011, 2014). The measure used for autism traits (AQ or RAADS-14) would not be responsible for the inconsistencies between the results.

It is important to note that the findings of this study may not necessarily apply to other cognitive domains, tasks, or daily activities. The extent to which metacognition is domain-general or domain-specific is still under debate (Faivre et al., 2018; Rouault et al., 2018a). If metacognition is domain-general, good performance in visual perceptual tasks may also imply good performance in memory tasks or other perceptual modalities (Faivre et al., 2018; Rouault et al., 2018a).

Despite not finding a significant relationship between metacognition and autistic traits in this study, it is important to keep in mind that the results obtained by measuring autistic traits in the general population may not be generalizable to a diagnosed autistic population (Carpenter et al., 2019b; Karvelis, 2020). Therefore, it is possible that altered metacognitive sensitivity may only be observed in a diagnosed autistic sample, as seen in studies by Nicholson et al. (2020) and Van der Plas et al. (2021). Further research should also explore whether metacognition is related to autism in a specific way, as this could help explain inconsistencies in previous studies' findings and provide a deeper understanding of the relationship between autism and metacognition.

A possible limitation of this study is that we did not take into account the potential impact of co-occurring conditions or traits that have been previously associated with metacognition, such as anxiety (Hoven et al., 2019; Rouault et al., 2018b; Seow et al., 2021), depression (Hoven et al., 2019; Fu et al., 2005; Rouault et al., 2018b; Seow et al., 2021), obsessive–compulsive disorder (Hoven et al., 2019; Rouault et al., 2018b; Seow & Gillan, 2020; Seow et al., 2021; Hoven et al., 2022), schizophrenia (Hoven et al., 2019; Seow et al., 2021) or nicotine dependence (Soutschek et al., 2022). Future research could address these limitations.

5. Conclusion

The current study aimed to examine the relationship between autistic traits, as measured by the AQ test, and metacognition in a sample of individuals from the general population. The results revealed no significant associations between metacognitive sensitivity and autistic traits or any of the AQ subscales. Additionally, no significant relationship was found between confidence and autistic traits. These findings suggest that the relationship between metacognition and autism may be more complex than previously thought and that other variables may be involved. The study contributes to the understanding of the relationship between metacognition and autism. Further research should investigate the nuances of this relationship, as this has important implications for both theory and practice.

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CRediT authorship contribution statement

Iair Embon: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Sebastián Cukier:** Supervision, Validation, Writing – original draft, Writing – review & editing. **Alberto Iorio:** Supervision, Validation, Writing – original draft, Writing – review & editing. **Pablo Barttfeld:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Guillermo Solovey:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Supplemental materials

All the data, including the code used to run the experiment and to analyze the data, as well as the code to reproduce the figures, is available at the following location: https://github.com/iair-embon/metacog-autistic-traits-2022.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All data used in this study, the code to run the experiment, the code to perform data analysis and to reproduce all figures is available at: https://github.com/iair-embon/metacog-autistic-traits-2022

Appendix

Table A1
The linear regression model results used to study the relationship between autistic traits and metacognitive sensitivity (meta-d').

	Beta	SE	95% CI	p-value	q-value
Intercept	0.954	0.032	0.891, 1.018	**<0.001**	**<0.001**
AQ.std	−0.007	0.034	−0.073, 0.060	0.844	0.857
Gender[m]	−0.011	0.061	−0.130, 0.108	0.857	0.857
Age.std	0.005	0.027	−0.048, 0.058	0.856	0.857
AQ.std * Gender[m]	−0.021	0.058	−0.135, 0.093	0.720	0.857
AQ.std * Age.std	−0.014	0.029	−0.072, 0.044	0.637	0.857
R2	0.002				
Adjusted R2	−0.012				
Power	0.1				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical.

Table B1
The linear regression model results used to study the relationship between autistic traits and metacognitive sensitivity (meta-d') without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.951	0.027	0.898, 1.003	**<0.001**	**<0.001**
AQ.std	−0.015	0.027	−0.068, 0.037	0.570	0.570
R2	0.001				
Adjusted R2	−0.002				
Power	0.09				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing;.std = Standardized; In bold: Statistical.

Table C1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive sensitivity (meta-d').

	Beta	SE	95% CI	p-value	q-value
Intercept	0.957	0.032	0.893, 1.020	**<0.001**	**<0.001**
Social Skill.std	−0.011	0.033	−0.076, 0.054	0.745	0.844
Attention Switching.std	−0.031	0.029	−0.087, 0.026	0.288	0.577
Attention to Detail.std	−0.018	0.028	−0.072, 0.036	0.519	0.831
Communication.std	0.057	0.033	−0.008, 0.123	0.083	0.333
Imagination.std	−0.039	0.028	−0.094, 0.015	0.154	0.410
Gender[m]	−0.019	0.060	−0.137, 0.099	0.749	0.844
Age.std	0.005	0.028	−0.049, 0.060	0.844	0.844
R2	0.017				
Adjusted R2	−0.002				
Power	0.4				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

Table D1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive sensitivity (meta-d') without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.951	0.027	0.898, 1.003	**<0.001**	**<0.001**
Social Skill.std	−0.010	0.033	−0.074, 0.054	0.762	0.762
Attention Switching.std	−0.032	0.028	−0.088, 0.024	0.262	0.393
Attention to Detail.std	−0.020	0.027	−0.073, 0.034	0.468	0.562
Communication.std	0.056	0.033	−0.009, 0.120	0.089	0.266
Imagination.std	−0.039	0.027	−0.093, 0.015	0.154	0.307
R2	0.017				
Adjusted R2	−0.002				
Power	0.1				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing;.std = Standardized; In bold: Statistical significance.

Table E1
The linear regression model results used to study the relationship between autistic traits and metacognitive efficiency (m-ratio).

	Beta	SE	95% CI	p-value	q-value
Intercept	0.726	0.025	0.676, 0.776	**<0.001**	**<0.001**
AQ.std	−0.013	0.026	−0.065, 0.039	0.636	0.974
Gender[m]	0.002	0.048	−0.092, 0.095	0.974	0.974
Age.std	0.004	0.021	−0.038, 0.045	0.869	0.974
AQ.std * Gender[m]	0.005	0.045	−0.085, 0.094	0.921	0.974
AQ.std * Age.std	−0.013	0.023	−0.058, 0.033	0.582	0.974
R2	0.002				
Adjusted R2	−0.012				
Power	0.09				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical.

Table F1
The linear regression model results used to study the relationship between autistic traits and metacognitive efficiency (m-ratio) without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.728	0.021	0.687, 0.770	**<0.001**	**<0.001**
AQ.std	−0.011	0.021	−0.052, 0.030	0.598	0.598
R2	0.001				
Adjusted R2	−0.002				
Power	0.08				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing;.std = Standardized; In bold: Statistical.

Table G1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive efficiency (m-ratio).

	Beta	SE	95% CI	p-value	q-value
Intercept	0.728	0.025	0.679, 0.778	**<0.001**	**<0.001**
Social Skill.std	0.002	0.026	−0.048, 0.053	0.925	>0.999
Attention Switching.std	−0.018	0.023	−0.062, 0.027	0.432	0.691
Attention to Detail.std	−0.018	0.022	−0.060, 0.025	0.415	0.691
Communication.std	0.034	0.026	−0.017, 0.085	0.192	0.513
Imagination.std	−0.036	0.022	−0.078, 0.007	0.098	0.393
Gender[m]	0.000	0.047	−0.093, 0.093	>0.999	>0.999
Age.std	0.004	0.022	−0.039, 0.046	0.868	>0.999
R2	0.016				
Adjusted R2	−0.004				
Power	0.35				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

Table H1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive efficiency (m-ratio) without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.728	0.021	0.687, 0.769	**<0.001**	**<0.001**
Social Skill.std	0.003	0.026	−0.048, 0.053	0.916	0.916
Attention Switching.std	−0.018	0.022	−0.062, 0.026	0.415	0.498
Attention to Detail.std	−0.018	0.021	−0.060, 0.023	0.390	0.498
Communication.std	0.034	0.026	−0.017, 0.084	0.191	0.381
Imagination.std	−0.036	0.021	−0.078, 0.007	0.099	0.297
R2	0.016				
Adjusted R2	0.002				
Power	0.08				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing;.std = Standardized; In bold: Statistical significance.

Table I1
The linear regression model results used to study the relationship between autistic traits and metacognitive sensitivity (AUROC2) without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.621	0.003	0.615, 0.627	**<0.001**	**<0.001**
AQ.std	−0.001	0.003	−0.007, 0.005	0.734	0.734
R2	0.000				
Adjusted R2	−0.002				
Power	0.063				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing;.std = Standardized; In bold: Statistical significance.

Table J1
The mixed logistic regression model results to study of the relationship between autistic traits and metacognitive sensitivity without controlling for gender and age.

	log(OR)	SE	95% CI	p-value	q-value
Intercept	0.285	0.028	0.231, 0.340	**<0.001**	**<0.001**
Confidence.norm	1.452	0.048	1.357, 1.546	**<0.001**	**<0.001**
Confidence.norm * AQ.std	−0.044	0.025	−0.093, 0.006	0.087	0.087
Subjects SE(intercept)	0.202				
Deviance	43,050				
Power for Confidence.norm * AQ.std	0.4				

Note. OR = Odds Ratio; SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; Statistical significance;.norm = normalized;.std = Standardized.

Table K1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive sensitivity (AUROC2) without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.621	0.003	0.615, 0.627	**<0.001**	**<0.001**
Social Skill.std	−0.004	0.004	−0.011, 0.003	0.290	0.435
Attention Switching.std	−0.003	0.003	−0.009, 0.003	0.368	0.441
Attention to Detail.std	−0.000	0.003	−0.006, 0.006	0.923	0.923
Communication.std	0.007	0.004	0.000, 0.015	**0.044**	0.131
Imagination.std	−0.004	0.003	−0.010, 0.002	0.190	0.379
R2	0.017				
Adjusted R2	0.004				
Power	0.113				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing;.std = Standardized; In bold: Statistical significance.

Table L1
The linear regression model results used to study the relationship between autistic traits and confidence without controlling for gender and age.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.000	0.053	−0.104, 0.104	0.999	>0.999
AQ.std	0.062	0.053	−0.042, 0.166	0.241	0.481
R2	0.004				
Adjusted R2	0.001				
Power	0.095				

Note. SE = Standard Error; CI = Confidence Interval;q-value = False discovery rate correction for multiple testing;.std = Standardized.

Table M1
The linear regression model results used to study the relationship between autistic traits and metacognitive sensitivity (AUROC2) when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.603	0.004	0.595, 0.611	**<0.001**	**<0.001**
AQ.std	−0.006	0.004	−0.014, 0.002	0.168	0.241
Gender[m]	0.012	0.006	0.000, 0.024	0.057	0.114
Age.std	−0.010	0.004	−0.017, −0.003	**0.004**	**0.013**
AQ.std * Gender[m]	−0.007	0.006	−0.018, 0.004	0.200	0.241
AQ.std * Age.std	0.001	0.004	−0.006, 0.009	0.716	0.716
R2	0.037				
Adjusted R2	0.027				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

Table N1
The mixed logistic regression model results to study of the relationship between autistic traits and metacognitive sensitivity when exclusion criteria are removed.

	log(OR)	SE	95% CI	p-value	q-value
Intercept	0.249	0.028	0.193, 0.304	**<0.001**	**<0.001**
Confidence.norm	1.411	0.042	1.328, 1.494	**<0.001**	**<0.001**
Confidence.norm * AQ.std	−0.069	0.032	−0.131, −0.007	**0.029**	0.068
Confidence.norm * Gender[m]	0.069	0.045	−0.020, 0.158	0.129	0.151
Confidence.norm * Age.std	−0.044	0.027	−0.097, 0.010	0.110	0.151
Confidence.norm * AQ.std * Gender[m]	−0.063	0.041	−0.143, 0.017	0.122	0.151
Confidence.norm * AQ.std * Age.std	−0.013	0.030	−0.071, 0.046	0.669	0.669
Subjects SE(intercept)	0.355				
Deviance	56,274				

Note. OR = Odds Ratio; SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male; Statistical significance;.norm = normalized;.std = Standardized.

Table O1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive sensitivity (AUROC2) when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.603	0.004	0.595, 0.611	**<0.001**	**<0.001**
Social Skill.std	−0.006	0.004	−0.015, 0.002	0.142	0.243
Attention Switching.std	−0.005	0.004	−0.012, 0.003	0.215	0.261
Attention to Detail.std	−0.002	0.004	−0.009, 0.005	0.605	0.605
Communication.std	0.005	0.004	−0.003, 0.014	0.228	0.261
Imagination.std	−0.009	0.004	−0.016, −0.002	**0.017**	**0.046**
Gender[m]	0.008	0.006	−0.003, 0.020	0.152	0.243
Age.std	−0.010	0.004	−0.017, −0.003	**0.006**	**0.023**
R2	0.047				
Adjusted R2	0.032				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

Table P1
The linear regression model results used to study the relationship between autistic traits and confidence when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	−0.002	0.055	−0.110, 0.106	0.972	0.972
AQ.std	0.042	0.057	−0.070, 0.155	0.458	0.972
Gender[m]	−0.005	0.082	−0.167, 0.157	0.952	0.972
Age.std	−0.006	0.047	−0.099, 0.087	0.897	0.972
AQ.std * Gender[m]	0.035	0.077	−0.117, 0.186	0.651	0.972
AQ.std * Age.std	0.006	0.052	−0.097, 0.108	0.916	0.972
R2	0.004				
Adjusted R2	−0.007				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized.

Table Q1
The linear regression model results used to study the relationship between autistic traits and metacognitive sensitivity (meta-d') when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.881	0.036	0.809, 0.952	**<0.001**	**<0.001**
AQ.std	−0.050	0.038	−0.125, 0.025	0.189	0.489
Gender[m]	0.045	0.055	−0.062, 0.153	0.407	0.489
Age.std	0.011	0.032	−0.051, 0.073	0.725	0.725
AQ.std * Gender[m]	−0.044	0.051	−0.144, 0.057	0.395	0.489
AQ.std * Age.std	−0.040	0.035	−0.108, 0.029	0.254	0.489
R2	0.015				
Adjusted R2	0.004				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical.

Table R1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive sensitivity (meta-d') when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.890	0.036	0.819, 0.961	**<0.001**	**<0.001**
Social Skill.std	−0.053	0.039	−0.129, 0.023	0.173	0.277
Attention Switching.std	−0.075	0.033	−0.140, −0.010	**0.023**	0.094
Attention to Detail.std	0.009	0.032	−0.054, 0.071	0.786	0.786
Communication.std	0.059	0.039	−0.017, 0.136	0.130	0.260
Imagination.std	−0.062	0.032	−0.125, 0.001	0.055	0.146
Gender[m]	0.015	0.052	−0.087, 0.117	0.777	0.786
Age.std	0.014	0.032	−0.049, 0.076	0.667	0.786
R2	0.030				
Adjusted R2	0.014				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

Table S1
The linear regression model results used to study the relationship between autistic traits and metacognitive efficiency (m-ratio) when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.639	0.024	0.592, 0.686	**<0.001**	**<0.001**
AQ.std	−0.035	0.025	−0.084, 0.014	0.157	0.315
Gender[m]	0.074	0.036	0.003, 0.144	**0.041**	0.122
Age.std	0.012	0.021	−0.028, 0.053	0.555	0.555
AQ.std * Gender[m]	−0.040	0.034	−0.106, 0.026	0.234	0.351
AQ.std * Age.std	−0.019	0.023	−0.064, 0.025	0.391	0.469
R2	0.023				
Adjusted R2	0.012				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical.

Table T1
The linear regression model results used to study the relationship between the subscales of the AQ and metacognitive efficiency (m-ratio) when exclusion criteria are removed.

	Beta	SE	95% CI	p-value	q-value
Intercept	0.643	0.024	0.597, 0.690	**<0.001**	**<0.001**
Social Skill.std	−0.031	0.025	−0.081, 0.019	0.220	0.352
Attention Switching.std	−0.038	0.022	−0.081, 0.005	0.081	0.215
Attention to Detail.std	0.001	0.021	−0.040, 0.042	0.967	0.967
Communication.std	0.019	0.026	−0.031, 0.070	0.449	0.581
Imagination.std	−0.041	0.021	−0.083, 0.000	0.051	0.206
Gender[m]	0.053	0.034	−0.014, 0.120	0.122	0.244
Age.std	0.014	0.021	−0.027, 0.055	0.509	0.581
R2	0.028				
Adjusted R2	0.013				

Note. SE = Standard Error; CI = Confidence Interval; q-value = False discovery rate correction for multiple testing; [m] = male;.std = Standardized; In bold: Statistical significance.

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