Exploring the relationship between autism spectrum disorder traits and metacognition sensitivity*

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Abstract. Given the large amounts of data that are currently acquired and manipulated, a new field called Computational Psychiatry has emerged. One of the best examples where computational psychiatry has contributed to neurodevelopmental syndromes comes from the study on Autism Spectrum Disorder (ASD). One of the current problems to which attention has recently begun to be paid is whether or not people with ASD have altered metacognition. The importance of exploring metacognition in ASD lies in practical and theoretical implications. However, the results found by studies exploring metacognition in people with ASD are inconsistent with each other. Only one study has utilized a bias-free measure of metacognition as in the present study. The main objective of this study was to contribute to the debate, through the study of metacognition in ASD traits in a sample of neurotypical people in an online experiment with a perceptual task. The results have not shown a statistically significant relationship between ASD traits and metacognition. These results are consistent with some of the previous studies.

Keywords: Computational Psychiatry · Online Experiment · Metacognition · Autism Spectrum Disorder

1 Introduction

In the present age, where large amounts of data are acquired and manipulated, a new field called computational psychiatry has recently emerged [31, 18, 12, 8, 17].

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It combines multiple levels and types of computing techniques with different data types to improve the understanding, prediction, and treatment of mental illness [31, 18, 12]. One of the fields where computational psychiatry has contributed comes from the study on Autism Spectrum Disorder (ASD) [12]. ASD is a neurodevelopmental disorder characterized by behavioral difficulties in social communication and social interaction, as well as restrictive or repetitive interests or behaviors [1]. When these traits are severe enough the person receives the clinical diagnosis of ASD. But, from a dimensional perspective, it is possible to evaluate ASD traits in neurotypical people. Since the characteristics on which the diagnosis is based are usually present, subthreshold in the general population, with ASD being one extreme of a dimension that crosses to the entire population [4].

One of the current problems to which attention has recently begun to be paid is whether or not people with ASD have altered metacognition [16, 34, 30, 15, 36, 35, 27, 22, 21, 5, 28]. Metacognition is defined as the ability to evaluate one's cognitive processes in various domains [24, 9, 25, 23, 10]. One way to study this ability under laboratory conditions is through behavioral experiments, in which participants have to make simple decisions and then report confidence that their decision was correct. In this type of task, metacognitive sensitivity is operationally defined as the ability to discriminate between correct and incorrect decisions based on confidence. For example, a participant with high metacognitive sensitivity would be more confident of having made correct decisions that were correct than those that were wrong [11].

The importance of exploring metacognition in ASD lies in practical [35, 21, 5, 16] and theoretical [5, 28, 16] implications. However, the results found by studies exploring metacognition in people with ASD are inconsistent with each other. Some studies suggest that metacognition would be altered in people with ASD, being lower in the latter [27, 28, 16]. Other studies do not observe differences concerning neurotypical people [30, 15, 36, 22, 21, 37]. Also, some studies have found mixed results [34, 35, 5]. Furthermore, it is possible to contribute to the debate by studying the relation between metacognition and ASD traits. To our knowledge, there are only two studies that assess metacognition about ASD traits [35, 5]. One of them did not observe a significant relationship between metacognition and ASD traits [35], while the other found a negative relationship: as the trait score increased, the metacognition score decreased [5]. If there was a relationship between them, it would be very important to control it when comparing the metacognition of an ASD group with that of a neurotypical group. Though some studies did it [15, 35, 27, 22, 5, 28, 16], others did not [34, 30, 36, 21, 37].

One last point that is important to consider refers to the different ways of measuring metacognition [11]. Some studies [5, 15, 16, 22, 27, 30, 35, 37] have measured the metacognition score by calculating gamma correlations [14, 26]. The problem with this measure is that it can be influenced by metacognitive bias [11]. Other studies have used ANOVA and t-test [21, 27, 34, 36]. Only one study [28] have utilized Meta ‘d, which is a bias-free measure [11]. In the present study, we used another bias-free measure of metacognition, the type two ROC analysis (AUROC2) [11]. Unlike Nicholson et al. [28], the present study has a sample of 457 adult neurotypical participants, rather than 25 children/adolescents with ASD and 25 neurotypical children/adolescents.

Given the inconsistencies in the results about the relationship between metacognition and ASD, and its practical and theoretical implications, it is very important to further research on this topic. Thus, the main objective of this study was to observe the relationship between ASD traits and metacognitive sensitivity, to contribute to the debate through the study of metacognition in ASD traits in a sample of neurotypical people in an online experiment with a perceptual task. A negative relationship between ASD traits and metacognitive sensitivity was expected.

2 Method

2.1 Participants

Participants were contacted through a volunteers database and social media. 457 participants took part in the experiment and met the inclusion criteria (do not use psychotropic medication, not having a psychiatric diagnosis, and be over 18 years old). After that, we excluded participants using the following criteria: reporting not to have performed the experiment carefully (6 participants), having performance below 60 % (2 participants), having pressed the same confidence key more than 85% of the trials (25 participants), having fewer than 90 trials after filtering for reaction times (29 participants), and having an AUROC2 below 1.5 standard deviations from the mean (27 participants). We also excluded those participants who did not report an option of the binary gender male or female (8 participants; since they were very few to be taken into account in the regression model). We excluded from the analysis a total of 97 participants, a typical number for web based experiments [6]. Every participant who performed the experiment agreed with informed consent. This experiment was approved by the ethics committee of the Instituto de Investigaciones Psicológicas, Córdoba, Argentina.

2.2 Materials and methods

The participants completed the Autism-spectrum Quotient (AQ) [3] to obtain an Autism Spectrum Disorder traits measure. The AQ has been used in other studies that measure ASD traits [35, 5, 19]. Also, it has been used as screening in ASD studies in Argentina [2, 13]. The AQ has 50 self-report items where the participants have to answer each item with a Likert scale of four points, from "definitely disagree" to "definitely agree". The participant can score in a range of zero to 50. There are items where "definitely agree" and "slightly agree" sum a point and others where "definitely disagree" and "slightly disagree" sum a point. The online experiment was prepared on a free platform for online experiments called JATOS [20] and was programmed in JavaScript. All the stimuli were prepared in JavaScript. The two circles radius was calculated as 0.15 of the browser window width. Every dot had a radius of 10 pixels. The location of each stimulus took into account the participant's browser window width and height.

Experimental task (see Fig. 1 a). A perceptual task of visual modality was carried out. The trial started with a fixation cross that appeared in the center of the screen for 500ms. Then, two circles horizontally aligned were shown to the participant for 500ms, and the participant had to choose the circle with more dots, with the arrow buttons. After pressing an arrow button, the participant has to report his confidence that his previous choice was correct, through a Likert scale of four points from "I don't know" to "I am very sure". Before starting the task, the participant was told to sit at a distance of 60cm from the center of the screen, to try not to be distracted, to silence his cellphone, and the notifications of the computer. The difficulty of the task was controlled by a staircase procedure of one-up/two-down, so that each participant had a performance of 75 % approximately. This procedure is very important to quantify the metacognitive score [7]. The experimental task lasted 5min approximately, it has one block of 130 trials and 15 practice trials. The only difference between the experimental trials and the practice trial was that in the last ones the Likert scale has written "I don't know" under the one value and "I am very sure" under the four value.

2.3 Procedure

Once the participant starts the experiment, he has to read and agree with the informed consent to advance. After that, demographic questions were asked. Then, the participant performed 15 practice trials and 130 experimental trials. Finally, to control the quality of the data, the participant was told to answer sincerely the following two questions: "The quality of our investigation depends on the quality of the data we obtain. Please be honest if we can count on your answers." and "If there is something that happened during the experiment that you want to tell us or that we need to know about, please write it down here. For example "I had to answer the phone".

2.4 Data analysis

All the data were analyzed in R [32] through R Studio [29]. The graphics were made in ggplot2 library [33]. We discarded trials with reaction times (RT) greater than 5000ms and smaller than 200ms in the dot discrimination task (4.28% discarded), and trials with reaction times (RT) greater than 5000ms in the confidence task (0.07% discarded). We also discarded the first 20 trials of each participant, to allow the staircase to stabilize (see Fig. 2 a). With the remaining participants, the AQ score and the metacognition score were calculated. The metacognition score was calculated by the area under the type two ROC curve

(AUROC2) [11]. A higher area under the curve means higher metacognitive sensitivity.

In order to observe the relationship between ASD traits and metacognitive sensitivity, a linear regression analysis was performed using the lm function in R. In the fitted model, the predicted variable was the AUROC2 score and the predictors variables were the AQ score (normalized), gender, age (normalized) and the interactions between each variable and AQ score (AQ score and gender, AQ score and age), given the following equation: AUROC2 = α + AQ score $*$ β_1 + gender $*$ β_2 + age $*$ β_3 + AQ score:gender $*$ β_4 + AQ score:age $*$ β_5 + errors.

3 Results

The AQ score mean for the final sample was 17.38 (SD = 5.45 ; range = 6 - 35). For male sample the mean was 18.91 (SD = 5.73 ; range = 7 - 31) and for female sample the mean was 16.73 (SD = 5.20 ; range = 6 - 35). See Fig. 2 b and c.

The AUROC2 mean for the final sample was 0.62 (SD = 0.06 ; range = 0.51 - 0.78). The staircase procedure worked well keeping overall performance constant throughout the discrimination task (see Fig. 2 d). Also, a similar performance was observed for each participant.

The linear regression model (see Fig. 2 e) demonstrated that the standardized AQ score ($\beta = -0.001$, $p > 0.7$), gender ($\beta = 0.007$, $p > 0.8$), standardized age ($\beta = -0.006$, $p > 0.06$), the interaction between gender and the standardized AQ score ($\beta = -0.003$, $p > 0.6$), and the interaction between the standardized AQ score and the standardized age ($\beta = 0.004$, $p > 0.2$) were non-significant predictor of AUROC2. The overall model fit was $R^2 = 0.004$ (residual SD = 0.06).

4 Discussion

The objective of the present study was to explore the relation between metacognition and ASD traits in a sample of neurotypical participants, through bias-free measure of metacognition sensitivity. Thus, a linear regression model were carried out.

The results of the regression model did not show the AQ score as a significant predictor of the AUROC2 (see Fig. 2 e and f). It seems not support the idea that metacognition would be altered in people with ASD, in line with what has been reported by other studies [34, 30, 15, 36, 35, 22, 21, 5, 37]. Nevertheless, these results are inconsistent with other studies that report altered metacognition in people with ASD [34, 35, 27, 5, 28, 16].

So far, only one of the studies exploring the relationship between metacognition and ASD has used an unbiased measure of metacognition in addition to the present study. Nicholson et al. [28] observed in experiment 1 that children and adolescents with ASD exhibited lower explicit metacognition (the accuracy with which verbal metacognitive judgments can be made, as a confidence assessment) when compared to neurotypicals. One possibility is that metacognition is impaired only in adolescents or children with ASD, but not in adults, such as the sample of the present study.

Another difference from the Nicholson et al. [28] study sample was that they compared 25 controls with 25 people with ASD. The present study assessed ASD traits in 457 neurotypicals without including those with a psychiatric diagnosis. It is possible that the sample of the present study did not have the ASD traits necessary to observe that metacognition is impaired. That is, perhaps metacognition is impaired only in those individuals at the extreme end of this trait dimension. This is a possibility that should be investigated in future studies.

5 Conclusion and future directions

In the present study, the relationship between metacognitive sensitivity and ASD traits was explored in a neurotypical sample of 457 participants through an online experiment. In the results, it was observed that ASD traits do not predict metacognition. These results are consistent with some of the previous literature. However, they differ from the only study so far that explored the relationship between metacognition and ASD with a measure of metacognition free of bias. Future studies should continue to explore the relationship between metacognition and ASD.

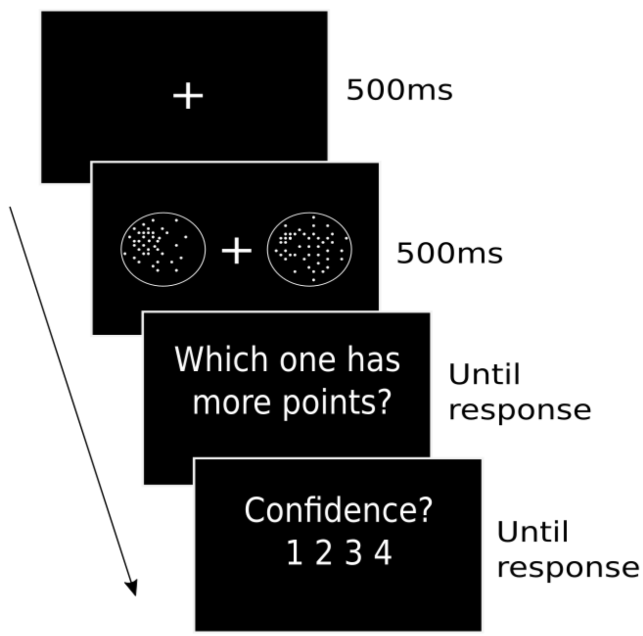

Fig. 1: Experimental task.

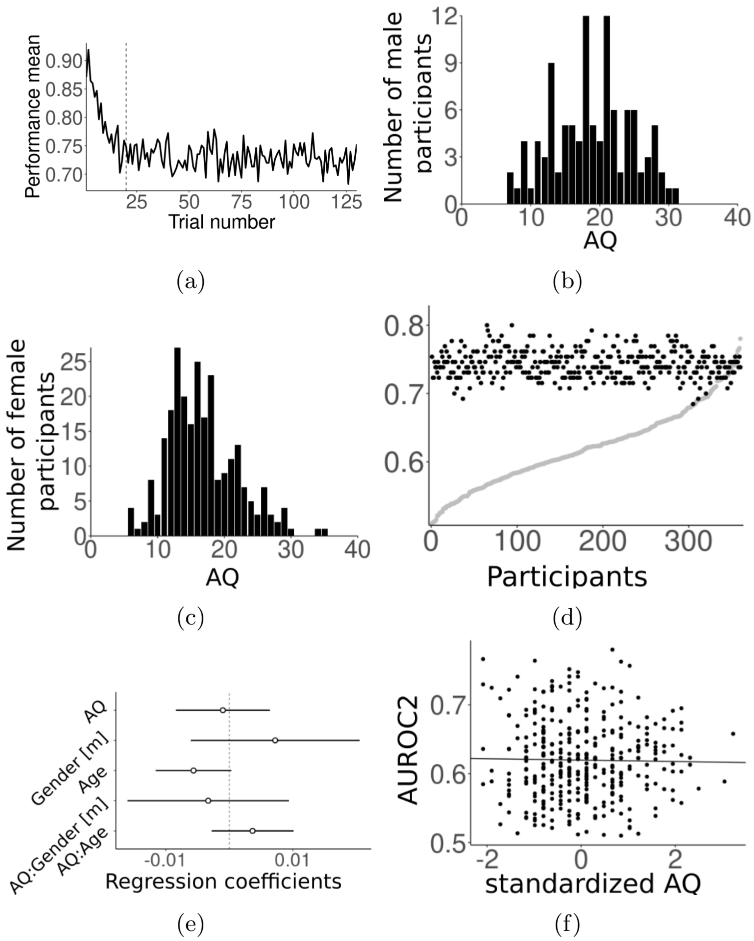

Fig. 2: a) Performance mean by trial. The dashed line is the cutoff trial. b) AQ score in male participants. c) AQ score in female participants. d) AUROC2 and performance by participants. e) Regression model coefficients. The dashed line is the zero value. f) Standardized AQ score and AUROC2.

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