

Dissociable Effects of Social and Non-Social Autistic Traits on Figure Disembedding and Mental Rotation in Women and Men

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Abstract

Recent data revealed dissociations between social and non-social domains both in autism and neurotypical population. In the present study, we investigated whether specific visuospatial abilities, as mental rotation and figure disembedding, are differently related to social and non-social autistic traits, also considering sex differences in dealing with visuospatial tasks. University students (N = 426) completed the Autism Spectrum Quotient (AQ), mental rotation of two-dimensional figures and figure disembedding tasks. A two-factor model of AQ was used to differentiate social and non-social autistic traits. Mental rotation was affected by a significant interaction between sex, social and non-social traits. This implies that, when non-social traits were above the mean (+ 1 SD), no sex differences in mental rotation were found, whereas, below this value, sex differences depended on the social traits, with men outperforming women at middle-to-high social traits, and with a comparable performance, or even with women outperforming men, at lower social traits. Instead, only a small positive correlation between figure disembedding and social traits was observed in the overall sample. These results are interpreted using the hyper-systemizing framework of autism and contribute to the debate on individual differences in the cognitive style of autistic people and neurotypical people with autistic traits.

Introduction

The issue of whether visuospatial abilities are superior in autistic people, also referred to as those with Autism Spectrum Conditions (ASC), compared to neurotypical individual has been debated for several decades [1–3] and still continues to attract attention of researchers [4, 5]. Amongst visuospatial tasks most expected to reveal differences between autistic people and those with typical development are mental rotation and figure disembedding, although there are conflicting results due to methodological differences across the studies [6]. Such discrepancies also appear when investigating the cognitive profile of neurotypical individuals with autistic traits.

Autistic traits exist across the general population, with clinical autism at the extreme end of a quantitative distribution [7, 8]. Neurotypical adults with high levels of autistic traits show superior performance compared to people with low autistic traits on figure disembedding tasks, analogous to what has been found in autistic individuals [9–11]. Larger inconsistencies are seen on mental rotation [12–15]. In particular, some authors found that different cognitive abilities and autistic traits predict mental rotation performance in women and men [14]. The interaction between traits and sex could led to differences both in performance [12] and the strategy used to solve mental rotation tasks [15]. Other authors found that an interaction between autistic traits and academic degree subject could account for differences in mental rotation in men and women [13].

Together, although these results are not fully consistent with respect to the relationship between autistic traits and mental rotation abilities, they converge in highlighting the need to test such relationships taking into account sex differences. Sex differences in mental rotation have been investigated for a long time,

reporting better abilities on average in men than women, although the size of the difference varies across studies [16–20], and some recent investigations report no difference at all [13, 21, 22].

Growing data in clinical autism are revealing dissociations between social and non-social domains [8, 23, 24]. Consistent with this, recent findings demonstrate that a dissociation between social and non-social autistic traits are also found in individuals with typical development [8, 24–26], thus strengthening the view that a continuity exists between clinical autism and autistic traits in the general population [7, 27, 28].

Russell-Smith et al. [11] distinguished social and non-social autistic traits using the Autism Spectrum Quotient (AQ; [7]) applying a two-factor model of the measure, differentiating social traits (“social interaction”) and non-social traits (“attention to detail”) [29]. The authors found that superior figure disembedding abilities were related to greater social but not non-social traits. Until now, the distinction between social and non-social traits has not been considered in studies investigating the influence of autistic traits on mental rotation. It is worth noting that better mental rotation abilities have been related to high systemizing [12–14]. Systemizing, defined as the preference for analysing, understanding and building systems, a strength of autistic individuals [30], embodies the non-social aspects of autism [24]. Mental rotation, requiring the person to deal with the visual stimulus as a variable that can be transformed (rotated) to predict how it will appear, involves systemizing [17, 31]. Systemizing has been operationalised as *‘if-and-then’* logical reasoning [32] and mental rotation nicely illustrates this: *If* I take a shape with a vertical element, *and* I rotate it 90 degrees anti-clockwise, *then* it will have a horizontal element.

Taken together, available data allow us to envisage the possibility that mental rotation and figure disembedding abilities are differently related to social and non-social autistic traits, with mental rotation most relating to non-social traits and figure disembedding to social traits. Importantly, these relationships could be moderated by sex. In the present study, we directly tested this hypothesis by verifying whether performance of women and men on mental rotation and figure disembedding tasks were differently related to social and non-social aspects of autistic traits, as assessed by the AQ [7].

Methods

Participants

Participants were 426 Italian native speaker students recruited (206 females, 220 males: mean age = 23.75 years, SD = 2.04) from different Universities in the Campania region (Southern Italy). All participants were recruited from systemizing-based degree subjects, as computer science, engineering, mathematics, chemistry, physics, biology, law, economics, languages and philosophy (for a detailed description of the degree subjects see [13]).

Individuals could participate to the study if they did not report any current or history of neurological or psychiatric conditions. Individuals with a diagnosis of neurodevelopmental disorder or reporting the past

or current use of substances acting on the central nervous system were also excluded from the study.

The study was approved by the Ethic Committee of the Department of Psychology of the University of Campania Luigi Vanvitelli, and was conducted in accordance with the ethical standards of Helsinki Declaration; written informed consent was obtained from all participants prior to testing.

Materials underpinning the research, and the datasets generated and analysed during the current study are available from the corresponding author (S.B.C.) on request.

Measures

Autistic traits

Autistic traits were assessed by means of the Italian version of the Autism Spectrum Quotient (AQ [7, 33]). The AQ measures, both in clinical and non-clinical samples, the individual's autistic traits through five domains (social skill, attention switching, attention to detail, communication and imagination). All the participants completed the full 50-item AQ, and the results were scored according to Baron-Cohen et al.'s [7] criteria. Thus, both a total AQ score and five scores for the main subscales (social skill, attention switching, attention to detail, communication and imagination) were obtained.

To evaluate social and non-social autistic traits we referred to the two-factor model of the AQ, allowing to distinguish a "social interaction" factor (i.e., social traits) from an "attention to detail" factor (i.e., non-social traits) [29]. The two factors were measured such that a higher score implies stronger autistic traits; namely, higher scores correspond respectively to greater social difficulties and greater attention to details.

Visuospatial abilities

Figure disembedding and mental rotation were assessed by two paper-and-pencil tests, both consisting of a series of items, each presented on a paper sheet. For each item, the target stimulus is placed in the upper part of the sheet while the options are placed in a six-choice display in the lower part of the sheet (Fig. 1). Participants are required to indicate among the six options the only one corresponding to the stimulus target. One point is assigned for each correct answer. For both tests, two practice items are given before the task in order to be sure that the participant clearly understands the instructions.

Figure disembedding

In the Hidden Figure Identification [34, 35], participants are presented with a target stimulus and six figures (i.e., the correct response and five distractors) consisting of complex geometrical shapes. The task requires participants to identify in the six-choice display the option representing a simple shape which is contained within the target stimulus. To give the correct answer, participants have to verbally report the number corresponding to the selected option. There are 12 items of increasing complexity (score range: 0–12).

Mental rotation

In the mental rotation task [34, 35], participants are presented with a target stimulus shaped as the capital letter L or S, with small white or black circles at the extremities. The six-choice display encloses the image corresponding to the target stimulus, rotated on the horizontal plane by 45°, 90°, 135°, or 180°, and five distractors that are mirror forms of the target stimulus at different degrees of rotation. The task requires participants to indicate the option matching the target stimulus after a rotation on the horizontal plane. To give the correct answer, participants have to verbally report the number corresponding to the selected option. There are 9 items of increasing complexity (score range: 0–9).

Statistical analysis

To assess the degree of association between social and non-social traits and the two visuospatial abilities, that is mental rotation and figure disembedding, Pearson correlation coefficients were computed between variables.

To investigate if figure disembedding and mental rotation abilities dissociate with respect to social and non-social autistic traits and if the effect is moderated by the sex, two hierarchical multiple regressions were carried out. In each regression, figure disembedding or mental rotation was regressed on the age (as control variable), sex and the two types autistic traits. In both regression models, all variables were included as z-scores but sex that was dummy coded (males = 0; females = 1). In the first step, the age was included. In the second step, sex, the social and non-social autistic traits were added. In the third step, the two-way interaction effects were added. In the fourth and final step, the three-way interaction was included. When significant, the interaction effects were investigated by applying simple slope analysis and the Johnson and Neyman's (JN) approach [36] to define the lower and upper values of the moderator for which the effect of the predictor on the dependent variable was significant. All the analyses were performed with the `psych` [37] and the `interaction` [38] packages implemented into R 3.6.1 software [39].

Results

Participants' performance on figure disembedding and mental rotation tasks as well as AQ scores, separately for females and males are reported in Table 1.

Table 1
Scores (mean and SD) on visuospatial tasks and AQ, separately for females and males.

	Females		Males	
	Mean	SD	Mean	SD
Visuospatial tasks				
Mental Rotation	6.4	2.29	6.7	2.1
Figure Disembedding	9.9	2.1	10.1	2.1
AQ				
Total	17.6	5.7	18.1	5.6
Social traits	11.7	5.1	12.6	4.9
Social skill	2.2	2.2	2.1	1.8
Attention switching**	4.4	1.9	4.8	1.8
Communication	2.4	1.9	2.5	1.7
Imagination***	2.7	1.6	3.3	1.7
Non-social traits (Attention to detail)*	5.9	2.4	5.5	2.5
Note. $N = 206$ females, 220 males; * $p = .044$; ** $p = .029$; *** $p = .0001$.				

Correlations

Results of the correlations analysis (Table 2) showed that figure disembedding was strongly associated with mental rotation performance. Moreover, data showed that figure disembedding was significantly associated with the social autistic traits, although the effect size was small. No other significant association ($p > .05$) between visuospatial abilities and autistic traits was observed.

Table 2. Correlations among social traits, non-social traits, mental rotation and figure disembedding performance.

Variables	1	2	3
1. Social traits	□		
2. Non-social traits	.042	□	
3. Mental rotation	.020	.023	□
4. Figure disembedding	.097*	.037	.431***

Note. * $p < .05$. ** $p < .01$. *** $p < .001$.

Regression models

As regards the figure disembedding task, the results of the hierarchical regression analysis did not show significant additive effects across the steps (Table 3). The regression analysis on the mental rotation showed that the model that included the three-way interaction increased the prediction of the dependent variable significantly, although the effect size was small, $R^2 = .016$; $F(1,415) = 6.808$, $p = .009$ (Table 3). Parameter analysis of the final model revealed that, independently of the other variables in the model, the effect of social traits on the mental rotation was moderated by both sex and the non-social traits. In particular, data showed that if the non-social traits are below the mean (-1 SD), the effect of social traits on mental rotation was positive for males (higher accuracy), whereas it was negative (lower accuracy) for females (Fig. 2). The JN analysis indicated that sex differences were significant when the social autistic traits were lower than -1.63 SD from the mean or higher than -0.03 SD from the mean. When non-social autistic traits were on the mean, sex differences of the effect of social traits on mental rotation were similar to what was described above but attenuated. Indeed, the JN analysis indicated that sex differences were significant when social autistic traits were higher than 0.01 SD from the mean. Whereas, when non-social traits were above the mean (+1 SD) no sex differences were observed as regards the effect of the social traits on the mental rotation. In other words, the interaction between social and non-social traits regulated sex differences in mental rotation performance.

Table 3

Hierarchical multiple regression analyses predicting visuospatial abilities from age, sex, the social and non-social autistic traits, and their interaction.

Visuospatial ability						
	Mental rotation			Figure disembedding		
Predictor	R^2_{diff}	b [95% CI]	β	R^2_{diff}	b [95% CI]	β
Step 1	.002			.007		
Age		0.046 [-0.057; 0.149]	.042		0.084 [-0.011; 0.179]	.084
Step 2	.007			.011		
Age		0.036 [-0.068; 0.139]	.033		0.078 [-0.018; 0.174]	.078
Sex (F = 1)		-0.365 [-0.793; 0.063]	-.083		-0.125 [-0.520; 0.270]	-.031
Social traits		0.022 [-0.195; 0.238]	.010		0.190 [-0.010; 0.390]	.091
Non-social traits		0.075 [-0.141; 0.292]	.033		0.072 [-0.128; 0.273]	.035
Step 3	.016			.014		
Age		0.033 [-0.071; 0.136]	.030		0.072 [-0.023; 0.168]	.072
Sex		-0.373 [-0.799; 0.053]	-.085		-0.133 [-0.527; 0.261]	-.033
Social traits		0.228 [-0.073; 0.529]	.101		.420** [0.143; 0.698]	.201**
Non-social traits		0.006 [-0.299; 0.311]	.003		-0.006 [-0.288; 0.276]	-.003
Sex · Social traits		-0.454* [-0.891; -0.018]	-.140*		-0.469* [-0.872; -0.065]	-.156*
Sex · Non-social traits		0.169 [-0.267; 0.606]	.053		0.145 [-0.258; 0.549]	.049

Note. $N = 426$. Age = age of participants in years (z-score); Sex = participants' sex dummy coding (Males = 0; Females = 1); * $p < .05$; ** $p < .01$; *** $p < .001$.

Visuospatial ability				
Social traits · Non-social traits	0.213 [-0.013; 0.439]	.092	-0.040 [-0.248; 0.169]	-.018
Step 4	.016*		.002	
Age	0.027 [-0.075; 0.130]	.025	0.070 [-0.025; 0.166]	.070
Sex	-0.416 [-0.841; 0.008]	-.094	-0.147 [-0.542; 0.248]	-.036
Social traits	0.207 [-0.092; 0.506]	.092	0.414** [0.135; 0.692]	.198**
Non-social traits	0.020 [-0.284; 0.323]	.009	0.002 [-0.284; 0.280]	.001
Sex · Social traits	-0.504* [-0.939; -0.068]	-.155*	-0.484* [-0.890; -0.079]	-.161*
Sex · Non-social traits	0.223 [-0.212; 0.659]	.070	0.163 [-0.243; 0.568]	.055
Social traits · Non-social traits	-0.070 [-0.379; 0.240]	-.030	-0.130 [-0.418; 0.158]	-.061
Sex · Social · Non-social traits	0.597** [0.147; 1.046]	.182**	0.191 [-0.227; 0.609]	.063
Total R ²	.041*		.034	
Note. N = 426. Age = age of participants in years (z-score); Sex = participants' sex dummy coding (Males = 0; Females = 1); *p < .05; **p < .01; ***p < .001.				

Discussion

Results showed that mental rotation performance was affected by a significant interaction between sex, social and non-social traits, implying that social traits differently impacted on sex differences in mental rotation at high, middle, and low values of non-social traits. More precisely, when non-social traits were above the mean (+ 1 SD), no sex differences in mental rotation were found, whereas, below this value, sex differences depended on the levels of social traits, with men outperforming women in the case of middle-to-high social traits, and with a comparable performance, or even with women outperforming men, at lower social traits. Instead, no interaction was found between sex and traits when considering performance on the figure disembedding task, but only a small positive correlation between figure disembedding and social traits suggesting that higher social traits were generally related with a better

figure disembedding performance. This last finding is consistent with Russell-Smith et al.'s [11] data, and also reveal that such a relationship, albeit weak, is independent from sex. Following recent evidence demonstrating that social and non-social autistic traits are dissociable even genetically [24], here we found that this was the case also when investigating the effects of social and non-social traits on a behavioral task as mental rotation. In this respect, mental rotation could be considered a behavioral proxy to non-social autistic traits, while is not true for figure disembedding.

The different effect social and non-social traits on mental rotation could involve the activation of different strategies to perform the task. Some authors suggest that mental rotation can be accomplished by two main strategies, global (holistic) and local (piecemeal) [40, 41]; the holistic strategy seems related to a better performance, whereas the piecemeal one to a poor performance [42]. Some have suggested that men on average may use a holistic strategy, whereas women on average may use a piecemeal strategy, although such differences have not been systematically confirmed [43, 44]. Recently, Stevenson and Nonack [15] studied eye fixations during mental rotation in women and men with low, medium and high autistic traits, as indexed by AQ total score. Results showed that fixations by the participants in the high autistic traits group varied by sex, while no sex differences were found for medium and low autistic traits, leaving unclear the possible mechanisms accounting for such a pattern of results. The present data underscore the importance to consider the extent to which persons differ in the degree of social and non-social autistic traits to clarify sex differences in mental rotation, because individual differences in non-social traits affect the way in which the individual deal with the task, possibly favouring activation of specific mental rotation strategies. Since a better performance may be related to a global strategy [42], one might suggest that higher non-social autistic traits would imply a stronger activation of the global approach both in women and man, thus flattening sex differences. Instead, at lower degrees of non-social traits, individual with higher social traits would tend to prefer a local strategy, being related to a lower accuracy. In the mental rotation literature, a global (or holistic) approach would imply that participants deal with the task by processing the elements of the to-be-rotated figures as integrated wholes, while the local approach would imply that the participants pay specific attention to the single components of the to-be-rotated figures through the entire mental rotation process [40, 45]. However, several scholars have pointed out that rather being divided into global vs. local, rotation strategies could be best divided based on their efficiency [46–48]. In particular, across several important studies, Just & Carpenter [47] demonstrated that the rotation process can be conceived as a piecemeal strategy since it entails a discrete, multi-step process in which the result of each step is monitored to determine if the intermediate result is approaching the final output. The authors also demonstrated that individuals performing better (high spatial subjects) are those who are able to keep track of the process, while individuals performing worse (low spatial subjects) are unable to keep track of the intermediate products of their partial rotations, so that their accuracy drops, especially at increasing task complexity. Just & Carpenter's [47] perspective nicely fits the concept of hyper-systemizing according to which individuals with high degrees of systemizing are able to understand a system by identifying the key elements or variables of the system, then manipulating them systematically and checking the effect of such manipulation on the system through "if-and-then" rules [31, 32]. Thus, solving a problem through systemizing implies, as a first

step of the process, detecting the crucial details of a complex whole (the system) then exploiting them to activate an “if-and-then”, multi-step process allowing system understanding and problem solution [31, 32, 49]. In the domain of mental rotation, people with higher systemizing or with high non-social autistic traits are prone to apply this multi-step process with high efficiency, thus performing better, as reported in the high spatial subjects, whereas people who perform low on mental rotation are less able to implement this multi-step process [47]. Indeed, our results showed that when non-social traits were below the mean there was the strongest sex difference with women being significantly low than men at higher social traits.

In summary, the present findings support the view that people with high non-social autistic traits show hyper-systemizing implying the capacity to step from details to the whole, also consistent the presence of talent in autistic people dealing with systemizing domains [31, 49]. In addition, high social autistic traits means the individual struggles with the capacity to move from details to the whole, leaving the individual stuck in the details. Since typical women, on average, are characterized by lower systemizing than men [30], this could account why men on average tend to outperform women on visuospatial tasks as mental rotation [12, 20]. Indeed, although men are generally higher than women in systemizing, not all men are high-systemizers and not all women are low-systemizers [13, 21, 31], thus when non-social traits are comparably high in women and men, a comparable mental rotation performance can be observed.

In conclusion, this study sheds light on the conflicting pattern of results in literature on the influence of autistic traits on mental rotation, paving the way for future investigations of this.

Declarations

Consortium

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Author Contributions

M.C. co-designed the study and wrote the first draft. V.P.S. conducted the analysis and wrote the results. I.Z., C.B. managed the data collection, prepared the figures and tables. V.W. edited the manuscript. The LabNPEE group collected the data. S.R., B.R., S.S. performed laboratory work. S.B.C. co-designed the study, edited the manuscript, and obtained funding for the study.

Competing Interests

The authors declare no competing interests.

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Figures

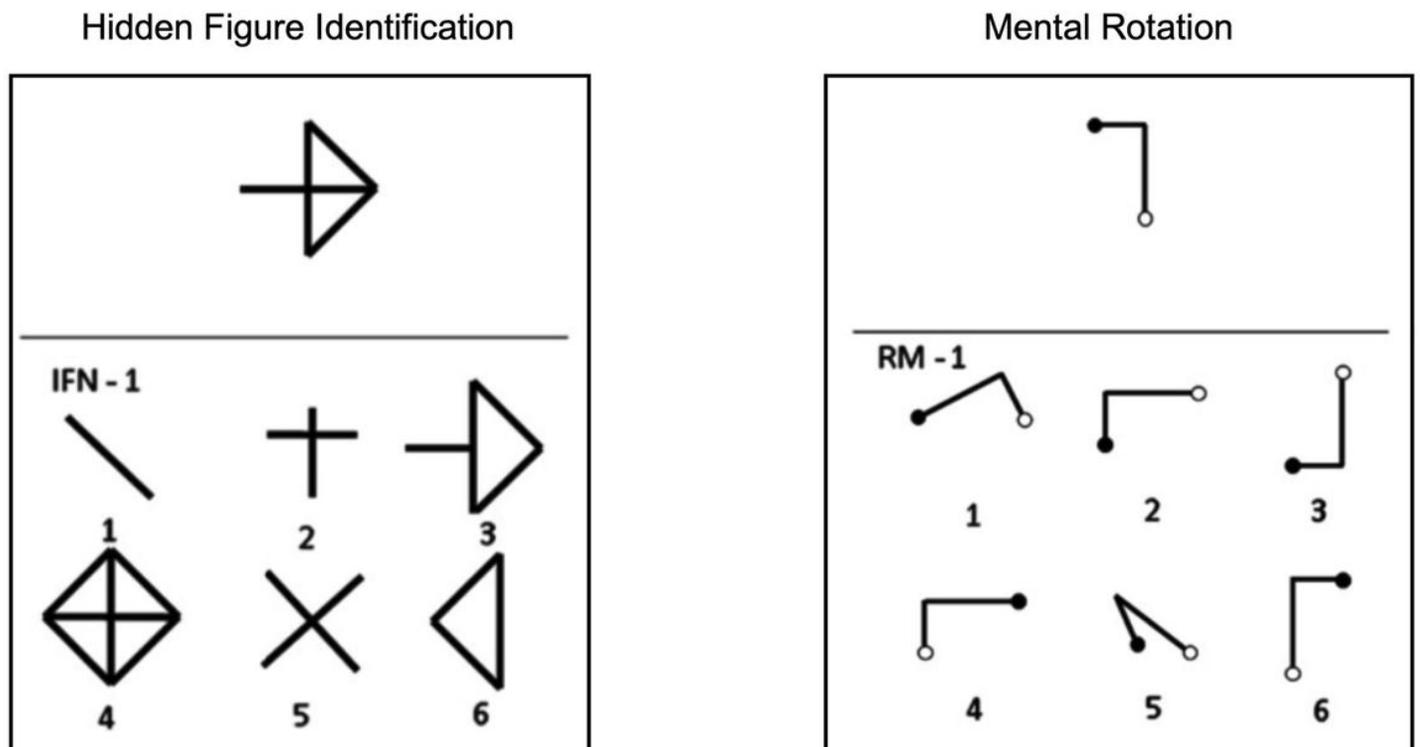


Figure 1

Examples of items from Hidden Figure Identification and Mental Rotation tasks. In the Hidden Figure Identification, participants have to identify among the six options a simple shape which is contained

within the target stimulus (here, the correct response is the option 3). In the Mental Rotation, participants are required to identify among the six options the one matching the target stimulus after a rotation on the horizontal plane (here, the correct response is the option 2).

AQ non-social (z score)

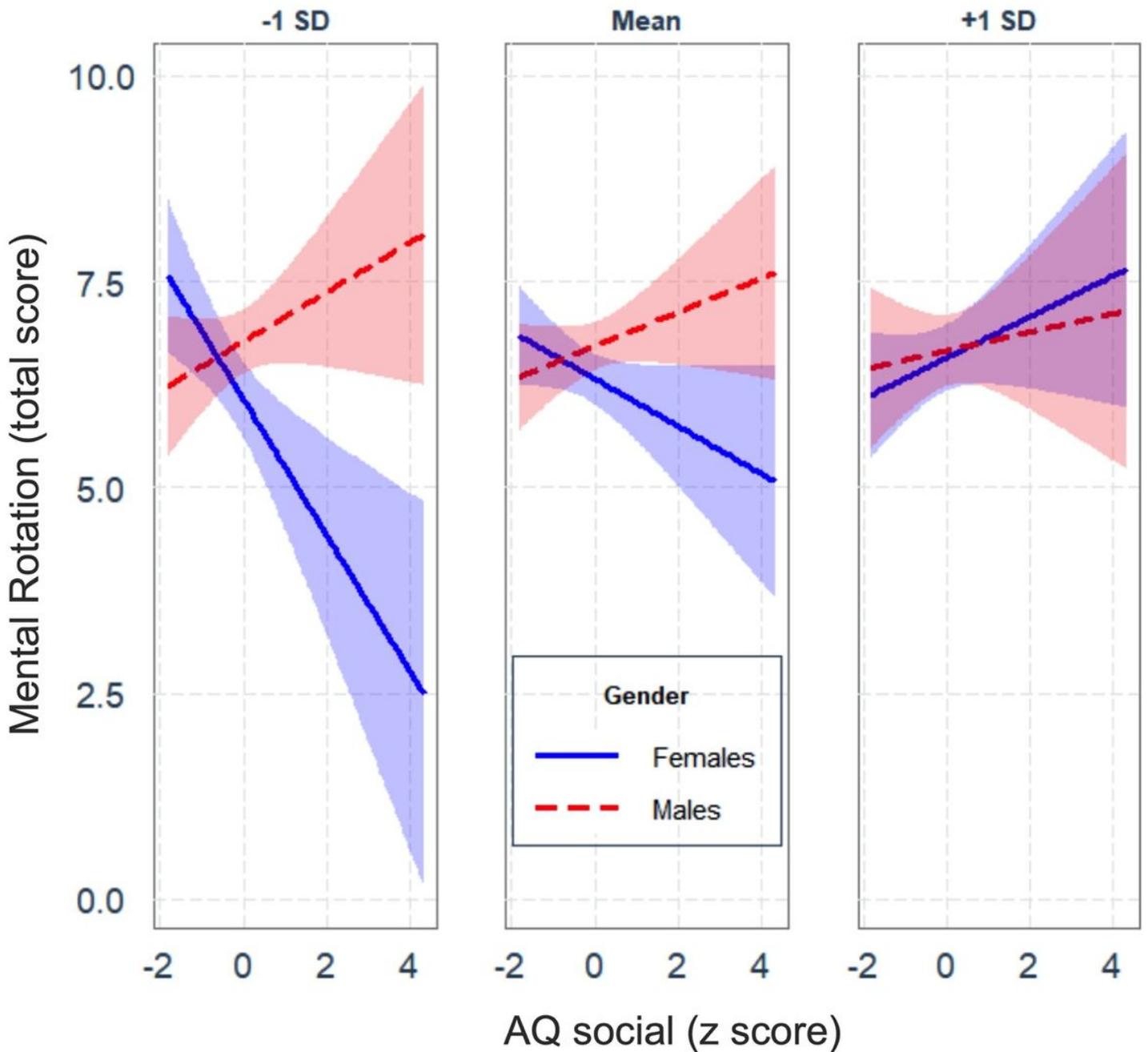


Figure 2

The effect of social traits on mental rotation performance moderated by both sex and non-social traits.