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Testing the social motivation theory of autism: the role of co-occurring anxiety

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Background: The *Social Motivation Theory* proposes that social reward processing differences underlie autism. However, low social motivation has also been linked to higher anxiety. Given the co-occurrence between autism and anxiety, it is possible that anxiety drives the association between social motivation and autistic characteristics. This study tests the mechanisms underlying the association between social motivation and autistic traits. **Methods:** Participants were 165 adolescents (71 male), aged 10–16 years, from the *Mapping profiles of cognition, motivation and attention in childhood (C-MAPS)* study, enriched for autistic traits (70 participants with an autism diagnosis, 37 male). Participants completed a battery of online experimental tasks, including a Choose-a-Movie social motivation task and social cognition measures (theory of mind; emotion recognition), alongside parent-reported child anxiety and autistic traits. **Results:** Higher social motivation was significantly associated with lower autistic traits ($\beta = -.26$, $p < .001$). Controlling for social cognition did not change the association between social motivation and autistic traits. Controlling for anxiety did significantly reduce the strength of the association (unstandardized coefficient change: $p = .003$), although social motivation remained associated with autistic traits ($\beta = -.16$, $p = .004$). Post hoc analyses demonstrated differential sex-effects: The association between social motivation and autistic traits was significant *only* in the females ($\beta = -.38$, $p < .001$), as was the attenuation by anxiety (unstandardized coefficient change: $p < .001$). **Conclusions:** The association between social motivation and autistic traits could be partially attributed to co-occurring anxiety. Sex-specific effects found in females may be due to environmental factors such as increased social demands in adolescent female relationships. Results are consistent with self-report by autistic individuals who do not identify as having reduced social motivation. **Keywords:** Social motivation; autism; social cognition; theory of mind; emotion recognition; adolescence.

Introduction

Autism is a neurodevelopmental condition characterised by social communication differences, restricted or repetitive behaviours (RRBs) and sensory atypicalities (Fifth ed.; DSM-5; American Psychiatric Association, 2013). The *Social Motivation Theory* (SMT; Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012) proposes that differences in social reward processing underlie autistic characteristics and reduce opportunities to develop social-cognitive skills. However, reduced social motivation has also been linked to increased anxiety in autism (Swain, Scarpa, White, & Laugeson, 2015). Given the high co-occurrence of autism and anxiety (Simonoff et al., 2008), it is possible that unmeasured anxiety drives the association between social motivation and autistic traits. This article aims to disentangle the mechanisms underlying the Social Motivation Theory of autism.

Social motivation is an innate drive which predisposes individuals to attend, seek out and take pleasure in the social world and maintain social relationships (Chevallier et al., 2012). According to the SMT, neural circuitry underlying social motivation functions atypically in autism, limiting interest in the social world, impacting social cognition [including theory of mind (ToM) and emotion recognition] and social skills. Support for the SMT comes from studies demonstrating differences between autistic and nonautistic individuals across key components of social motivation (Chevallier et al., 2012): *social orienting* (attending to social stimuli such as faces, eye-contact), *seeking-liking* (finding social stimuli rewarding and wanting them) and *social maintaining* (effort and interest in maintaining social bonds). Studies considering sex-based effects have consistently found females to demonstrate higher levels of social motivation than males (Chawarska, Macari, Powell, DiNicola, & Shic, 2016; Harrop et al., 2018; Sedgewick, Hill, Yates, Pickering, & Pellicano, 2016).

This study focuses on the social *seeking and liking* component of the SMT, which Dubey, Ropar, and Hamilton (2015, 2017) tested using an experimental Choose-a-Movie (CAM) paradigm measuring behavioural effort to view social and nonsocial stimuli. In nonautistic adults, higher autistic traits were associated with reduced preference for social stimuli

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(Dubey et al., 2015), and autistic teenagers showed a preference for nonsocial stimuli (Dubey et al., 2017). A meta-analysis by Hedger, Dubey, and Chakrabarti (2020) suggested that autistic differences in social-seeking were smaller than for social orienting; they suggest that social motivation may not be uniformly decreased in autism.

The SMT proposes that reduced social motivation limits opportunities to develop social-cognitive skills (Chevallier et al., 2012). Social-cognitive abilities, which include ToM and emotion processing, are often found to be reduced in autism (Baron-Cohen, Leslie, & Frith, 1985; Harms, Martin, & Wallace, 2010), although not universally so (Happé, 1995; Peterson, 2014; Senju, 2012). Limited research has examined the association between social motivation and social cognition. Garman et al. (2016) found that greater parent-reported persistence in social relationships with peers predicted poorer emotion recognition in autistic children. Burnside, Wright, and Poulin-Dubois (2017) found that, while social orienting and ToM were lower in autistic children, the measures were not significantly associated with one another. These findings contrast with the SMT's proposal that social motivation is a key antecedent of social-cognitive development.

Jaswal and Akhtar (2019) argue that the SMT relies on inaccurate, neurotypically biased interpretations of autistic behaviour, ignoring the dyadic nature of social interactions (Double Empathy Theory: Crompton, Ropar, Evans-Williams, Flynn, & Fletcher-Watson, 2020; Heasman & Gillespie, 2018; Milton, 2012). They suggest that social motivation is expressed idiosyncratically in autism, and therefore, may not be readily captured by experimental methods used in social motivation literature such as eye tracking. Further, Livingston, Shah, and Happé (2019) argue that some autistic behaviours, such as camouflaging of RRBs, are themselves evidence of atypically *high* social motivation in autism (Cook, Hull, Crane, & Mandy, 2021).

What else could explain the observed association between social motivated behaviours and autism? One possibility is the presence of co-occurring conditions, which are related to social motivation, and are highly prevalent in autistic populations, such as clinically elevated anxiety (Simonoff et al., 2008). Estimated rates of anxiety disorders in autistic individuals range from 17% (Van Steensel, Bögels, & Perrin, 2011) to 49% (Bellini, 2004), with higher anxiety rates in autistic females compared to males (Sedgewick, Leppanen & Tchanturia, 2020). These differential sex effects for anxiety are similar to those observed in neurotypical populations (Wright et al., 2023). Briot et al. (2020) identified a negative association between parent-reported social anxiety and the social motivation subscale of the Social Responsiveness Scale (SRS-2; Constantino & Gruber, 2012, a measure of autistic traits) in autistic children and adolescents, which was stronger than for any other subscale. Swain et al. (2015) and Factor, Condy, Farley, and Scarpa (2016) similarly identified a negative association between social motivation on the SRS and parent- and self-reported social anxiety. These findings suggest that co-occurring anxiety may account for the social motivation differences observed in autism.

It may be that individuals with low social motivation find social situations less enjoyable and more threatening. In support of this hypothesis, Corbett et al. (2014) found an association between decreased social motivation behaviours and elevated cortisol, a proposed index of stress, during a social interaction task in autistic children. Elevated anxiety levels relating to low social motivation could result in an increased rate of RRBs as a self-regulation strategy in social situations (Briot et al., 2020; Joosten, Bundy, & Einfeld, 2008), potentially driving up rates of observable autism traits. An alternative – although not mutually exclusive – possibility is that high social anxiety in autistic individuals predisposes them to use fewer 'socially motivated' behaviours as a means of avoiding anxiety-inducing social stimuli. Kliemann, Dziobek, Hatri, Baudewig, and Heekeren (2012) and Tottenham et al. (2014) demonstrated an association between amygdala hyperarousal and reduced social orientating during direct eye-gaze tasks in autistic individuals, consistent with the possibility that social anxiety accounts for reduced rates of social motivation behaviours reported in autistic individuals.

This study aims to test the factors underlying the association between autistic traits and social motivation, using an objective experimental CAM task (based on Dubey et al., 2015). Specifically, we will test whether controlling for individual differences in social cognition (operationalized as experimental measures of ToM and emotion recognition) or parent-reported anxiety traits (*Spence Child Anxiety Scale*, SCAS; Spence, 1997), can account for the association between social motivation and autistic traits.

Methods

Participants and study design

Participants in the *Mapping Profiles of Cognition, Motivation and Attention in Childhood* (C-MAPS) study were recruited via secondary schools, charities and social media. Targeted recruitment included schools for children with social, emotional and behavioural difficulties, with the aim of increasing variability in autistic traits, anxiety and other neurodevelopmental conditions. This approach of using trait dimensions is consistent with recent transdiagnostic shift in the field of psychiatry (Insel et al., 2010) and has been used previously in this sample (Carter Leno et al., 2023). Inclusion criteria were being 10–16 years of age, living in the United Kingdom and being fluent in English. Exclusion criteria were the child having genetic or psychotic conditions. As part of a battery of assessments (Appendix S1), parent-rated questionnaires were presented via Qualtrics (2022) in a quasi-random order and child-completed experimental tasks were presented online using Gorilla (2022). Autism diagnosis was recorded using parent-report of diagnostic label, who gave the diagnosis, and age of diagnosis (Appendix S2). Where two siblings took part ($N = 2$), data from one sibling was excluded at random. Full sample characteristics are reported in Table 1.

Participants included in this analysis ($N = 165$) had a verbal IQ (VIQ) score >70 and complete data on the social motivation task, parent-reported autistic and anxiety traits, ToM, emotion recognition accuracy and covariates: VIQ, biological sex, child age, parental education and distractions in the home environment (Appendix S3). We tested for group differences in parental education, CHAOS total score, child's age, sex, VIQ, ethnicity and autistic traits between the final analysis sample ($N = 165$) and the remaining sample who were excluded due to incomplete data ($N = 210$). The excluded sample had a significantly lower VIQ ($M = 107.35$) than the analytic sample ($M = 120.43$; $p = .02$), and lower scores on emotion recognition accuracy (excluded $M = 74.88$; analytic $M = 79.49$; $p = .01$). All other comparisons were nonsignificant ($ps > .10$). The high number of exclusions was because the study was run online and lots of parents started filling out the questionnaires, but their children did not go on to complete the experimental tasks.

Ethical considerations: All parents provided consent, and children provided assent. This study was approved by the Psychiatry, Nursing and Midwifery Research Ethics Committee, King's College London (HR-19/20-17193) and Bath Psychology Research Ethics Committee (20-199; 22-004).

Materials

Experimental measures. Social motivation: CAM task (see Dubey et al., 2015):

This experimental task captured participants' relative preference for viewing social stimuli, and the behavioural effort they were willing to exert to do so. On each trial, the participants were shown two patterned boxes. Each box was associated with either social (faces), or nonsocial (objects) stimuli. The pattern-stimulus association could be learned during practice trials and was counterbalanced across participants. 'Social' stimuli were images from the NIMH Child Emotional Faces picture set (Egger et al., 2011), which featured five male and five female children with happy faces, with direct outward gaze. Nonsocial stimuli were five high-interest and five low-interest images of household items as rated by autistic individuals (Sasson, Dichter, & Bodfish, 2012). This controlled for erroneous effects driven by focussed interests in autistic participants.

On each trial, participants 'unlocked' their selected box by clicking on images of padlocks, with a 1,000 ms forced delay between each padlock. This allowed behavioural effort to access stimuli to be quantified. After clicking on each of the padlocks, participants were presented with the associated image for 2000 ms. There were 60 trials. The ratio of padlocks on the two boxes was: 1:1 (12 trials), 2:1 (12 trials), 3:1 (24 trials) and 3:2 (12 trials). The ratios of padlocks were counterbalanced across stimulus types and position on the screen.

Social motivation scores were calculated from the proportion of 48 unbalanced padlock ratio trials on which social stimuli were viewed. A score of 50% indicates no preference driven by stimulus type. Scores >50% indicated a preference for viewing social stimuli; scores <50% indicated a preference for nonsocial stimuli. Similar effort-based measures of social reward have been implemented to success in both autistic and nonautistic participants (Ewing, Pellicano, & Rhodes, 2013; Hayden, Parikh, Deaner, & Platt, 2007).

Social cognition: ToM task (see Moraitopoulou et al., in press):

The Frith-Happé Animations Task (Abell, Happé & Frith, 2000) was used to capture participants' mental state attributions for abstracted social scenarios, an index of ToM. On each of five trials, participants were shown a silent video showing a pair of interacting cartoon triangles. The first trial showed a goal-directed animation of two triangles fighting. The remaining four animations showed mental-state-based interactions ('mocking', 'seducing', 'surprising' and 'coaxing'), which were presented in a random order. On each trial, participants were shown a fixation cross for 1,000 ms, followed by an animation lasting 34–45 s. Participants gave a typed description of what happened in the animation, which were coded from 0 to 2 for accuracy, by a single researcher, blinded to participants' diagnostic status. A second researcher double-coded 30 transcripts to test inter-rater reliability ($\alpha = .85$). Accuracy scores across the four mental state-based trials were averaged to yield an overall ToM score. Participants were excluded if their descriptions were incomplete or inconclusive for >2 mental state animations ($N = 2$). Findings from Livingston, Shah, White, and Happé (2021) support the validity of online administration of this task.

Social cognition: emotion recognition task (see Carter Leno et al., 2023):

Participants' abilities to recognise basic emotions were inferred from their performance on a multiple-choice emotion recognition task. On each of 20 trials (four trials per emotion), participants were presented with an image of a face portraying one of five emotions: happiness, sadness, anger, surprise or fear. Images were taken from Griffiths et al. (2019) and were controlled for emotional intensity (rated 6/8) to give sufficient variability in response accuracy. Four different face prototypes were used: two European faces (one male, one female) and two South Asian faces (one male, one female). Each trial consisted of a central fixation cross on the screen for 1,000 ms. The stimuli were then presented for 2000 ms, after which, participants were shown a forced multiple-choice screen with five emotion labels. The position of these labels was randomized across participants, but consistent across trials. The order of stimuli was randomized.

Mean emotion recognition accuracy was calculated from the percentage of trials on which participants correctly clicked on the emotion label matching the image shown on the previous screen. Trials with reaction times (RT) below 200 ms, or ≥3 standard deviations above the participant's mean RT (2.4% of trials) were excluded.

Verbal IQ: Receptive one word picture vocabulary test – Fourth edition (ROWPVT-4; Martin & Brownell, 2010):

Verbal IQ was measured to control for confounding effects of difficulties with understanding task instructions. On each trial, participants were shown four images of items, labelled 1, 2, 3 and 4, and heard an audio clip naming one of the items pictured. Participants were required to click on the item named in the audio clip. The audio clip could be replayed before selecting a box. Trials with a recorded response time of <200 ms (.2% of trials), or where visual or auditory stimuli were not properly loaded (<.1% of trials) were excluded from analyses. The ROWPVT-4 shows high internal consistency (Cronbach's $\alpha = .93–.97$) and test–retest reliability ($r = .97–.98$; Martin & Brownell, 2010).

Parent-reported measures. Autistic traits: Social Responsiveness Scale (SRS-2, Constantino & Gruber, 2012):

Parent ratings on this 65-item measure were used to capture participants' autistic traits in the following domains: Social Communication and Interaction (Social Awareness, Social Cognition, Social Communication, Social Motivation), and Restrictive Interests and Repetitive Behaviours. This measure uses a 4-point Likert scale (0 'not true' – 3 'almost always true'). Bölte, Poustka, and Constantino (2008) found strong psychometric properties in both

Table 1 Descriptive statistics

Variables	Min	Max	Autistic (*N* = 70) Mean (*SD*)	Nonautistic (*N* = 95) Mean (*SD*)	Tests of group differences[a] *p*
Autistic traits: SRSS[b]	0.00	140.00	86.90 (22.74)	39.67 (32.13)	<.001
Autistic traits: SCQ[c] total	0.00	31.00	19.94 (6.23)	7.29 (6.99)	<.001
Age of autism diagnosis	2	15	8.37 (3.28)	–	–
Social motivation score (%)	0.00	72.92	35.16 (18.87)	42.78 (16.37)	.01
Average theory of mind accuracy (/2)	0.00	2.00	.73 (.48)	.91 (.50)	.02
Emotion recognition accuracy	36.84	100.00	75.20 (13.49)	82.65 (10.04)	<.001
Anxiety: SCAS total[d]	0.00	89.00	38.67 (20.39)	23.84 (17.06)	<.001
Verbal IQ accuracy	92	181	144.14 (20.42)	150.79 (20.62)	.03
Verbal IQ *T* score	76	145	116.31 (19.24)	123.46 (16.25)	.01
Age (months)	120.33	202.62	158.33 (21.59)	156.80 (20.62)	.62
CHAOS score[e]	0	14	4.83 (3.95)	4.02 (3.68)	.18
Parental education[f]	0	1	.83 (.38)	.80 (.40)	.64
SDQ total[g]	0	35	19.24 (6.50)	11.04 (8.84)	<.001
Ethnicity			*N* (% of group)		
White			65 (92.86%)	78 (82.11%)	
Mixed race			2 (2.85%)	6 (6.32%)	
Black			1 (1.43%)	2 (2.11%)	
South Asian			1 (1.43%)	4 (4.22%)	
Other/Prefer not to say			1 (1.43%)	5 (5.26%)	
Participants meeting clinical cut-off			*N* (% of group)		
Social Responsiveness Scale (60)			96 (58.18%)		
			66 (94.29%)	27 (28.42%)	
Social Communication Questionnaire (15)			73 (44.24%)		
			59 (84.29%)	14 (14.74%)	
Spence Child Anxiety Scale			55 (33.33%)		
			37 (52.86%)	18 (18.95%)	

[a]Two-tailed *t*-test (equal variances not assumed) used for continuous variables and chi-square test used for binary variables.
[b]Sum score calculated by summing raw scores on Restrictive Interests and Repetitive Behaviours, Social Communication, Social Awareness and Social Cognition subscales from the Social Responsiveness Scale (SRS).
[c]Scores on Social Communication Questionnaire.
[d]SCAS – Spence Child Anxiety Scale.
[e]Scores on the Confusion, Hubbub and Order Scale.
[f]0 = below undergraduate degree level, 1 = above undergraduate degree level.
[g]Total score on the Strengths and Difficulties Questionnaire.

autistic and nonautistic adolescent samples: Test–retest reliability was good (*r* = .84–.97) and convergent validity with ADOS scores was moderate (*r* = .35). The 10 items making up the Social Motivation subscale were excluded to avoid collinearity in the regression model between social motivation and autistic traits. Internal consistency for the resulting measure was high (whole sample: α = .98, autistic participants: α = .93 and nonautistic participants: α = .98). SRS raw scores were used as a continuous measure of autistic traits.

Anxiety: The Spence Child Anxiety Scale (SCAS; Spence, 1997): Parent responses on this 38-item questionnaire were used to capture participants' current anxiety symptoms. Essau, Sasagawa, Anastassiou-Hadjicharalambous, Guzmán, and Ollendick (2011) demonstrated good internal consistency and validity in non–autistic samples. Jitlina et al. (2017) demonstrated that convergent validity in an autistic sample was mixed (*r* = .49 to .57). Internal consistency in this sample was high (whole sample α = .95, autistic participants: α = .94 and nonautistic participants: α = .95).

The Confusion, Hubbub and Order Scale (CHAOS) (Matheny, Wachs, Ludwig & Phillips, 1995): Parent responses on this 15-item scale were used to control for effects of distractions in the family home on experimental task performance. The CHAOS measure shows good test–retest reliability (*r* = .74) and high concurrent validity with direct measures of the physical and social environment (Matheny et al., 1995). Internal consistency in this sample was good (whole sample α = .86, autistic participants: α = .86 and nonautistic participants: α = .86).

Statistical analyses

Analyses were completed in IBM SPSS Statistics (IBM Corp, 2021, version 28) and Stata (StataCorp, 2021, version 17). Visual inspection of histograms and P–P plots indicated that linear regression models violated assumptions of normally distributed residuals. Robust estimation by bootstrapping (2000 resamples) was therefore used throughout.

To test the association between autistic traits and social motivation, SRS total score (removing the social motivation subscale) was regressed onto social motivation scores alongside covariates (VIQ, age, sex, parental education, CHAOS; Model 1). To test whether this association could be accounted for by differences in social cognition or anxiety, we conducted additional linear regression analyses, adding ToM and emotion regulation scores (Model 1a) and anxiety (SCAS) scores (Model 1b) and a joint model with both social cognition measures and anxiety together (Model 1c).

To test the relative impact of accounting for social cognition and anxiety, analyses tested for a significant change in unstandardized coefficients for social motivation when social cognition or anxiety was added to the regression model. This was achieved by dividing the absolute difference between unstandardized coefficients in the adjusted and unadjusted models by its own standard error, yielding a *t* statistic, which could be cross-referenced with degrees of freedom to find an associated *p* value (Clogg, Petkova, & Haritou, 1995; see Appendix S4 for Stata do-code).

Results

Table 1 shows descriptive statistics for participants split by parent-reported autism diagnostic status (see Appendix S5 for descriptives split by sex, and Appendix S6 for variable ranges by sex and diagnostic status).

Is the association between social motivation and autistic traits explained by social cognition and/or anxiety?

Table 2 shows raw correlations between variables across the whole data set. Social motivation scores were significantly negatively associated with autistic traits (SRS score): r (163) = −.21, p = .01. Both measures of social cognition were also significantly associated with autistic traits: ToM: r (163) = −.24, p = .002, emotion recognition: r (163) = −.22, p = .01. There was a strong positive association between autistic traits and anxiety scores: r (163) = .65, $p < .001$. Social motivation was not significantly associated with social cognition (ToM or emotion recognition) or anxiety.

In Model 1, autistic traits (SRS scores) were regressed onto social motivation alongside covariates (sex, age, verbal IQ, parental education and CHAOS). The effects of adjusting this model for ToM and emotion recognition (Model 1a), anxiety (Model 1b) and both measures of social cognition and anxiety together (Model 1c; see Table 3).

In Model 1, there was a significant negative association between social motivation and autistic traits (SRS score): $B = -0.53$, $SE = 0.14$, $p < .001$, 95% bootstrapped CI [−0.80, −0.26], $\beta = -.26$. Results controlling for diagnostic group showed that social motivation remained a significant predictor of SRS score ($B = -0.16$, $SE = 0.14$, $p < .001$). There was no significant interaction effect between diagnostic group and social motivation (see Appendix S7).

In Model 1a, social motivation remained a significant predictor of autistic traits after ToM and emotion recognition task performance were included as covariates ($B = -0.54$, $SE = 0.14$, $p < .001$, 95% bootstrapped CI [−0.81, −0.25], $\beta = -.26$). The unstandardized coefficient for social motivation was not significantly different after adjusting for social cognition ($t = 0.35$, $p = .73$).

Social motivation remained a significant predictor of autistic traits when anxiety was included as a covariate (Model 1b), ($B = -0.33$, $SE = 0.12$, $p = .004$, 95% bootstrapped CI [−0.56, −0.08], $\beta = -.16$). The unstandardized coefficient for social motivation was significantly reduced from the unadjusted model ($t = 3.11$, $p = .002$), see Figure 1.

Results of Model 1c, which included both social cognition and anxiety were highly similar to the model controlling for anxiety only (see Table 3).[1]

Post hoc analyses: sex-based effects.

Given the sex differences in social motivation (Sedgewick et al., 2016) and anxiety (Martini et al., 2022) in autism, we decided to run post hoc analyses testing for differential sex-effects. The interaction between social motivation and sex was marginally significant ($B = -0.61$, $SE = -0.01$, $p = .06$, $\beta = -.40$), so we stratified by sex (see Table 4 and Appendices S8 and S9).

There were 71 males and 94 females in this sample. An independent samples *t*-test demonstrated that scores for anxiety were not significantly different in males ($M = 28.62$, $SD = 20.30$) and females ($M = 31.28$, $SD = 19.62$), $t(148.12) = -0.84$, $p = .40$.

Linear regression analyses stratified by sex showed that the association between social motivation and autistic traits observed in Model 1 was significant in females ($B = -0.74$, $SE = 0.13$, $p < .001$, $\beta = -.38$), not in males ($B = -0.04$, $SE = 0.32$, $p = .90$, $\beta = -.02$). Similarly, adjusting for anxiety significantly reduced the unstandardized coefficient for social motivation *only in females*, driving the effect seen in the overall sample (females: $t = 5.79$, $p < .001$, males: $t = 0.51$, $p = .61$; see Figure 1).

Discussion

This study aimed to test the factors underlying the reported association between social motivation and autistic traits. Replicating previous findings, we found a significant negative association between social motivation and autistic traits (Dubey et al., 2015). Regression analyses suggested that co-occurring anxiety, but not social-cognitive abilities (ToM; emotion recognition) may partially account for this association. Further, follow-up analyses showed differential sex-specific effects, with significant associations driven by females.

According to SMT 'motivational deficits' are proposed to lead to reduced social cognition, irrespective of autism diagnosis (Chevallier et al., 2012). In contrast, this study found no significant association between social motivation and social cognition (for ToM or emotion recognition). This extends findings from Burnside et al. (2017) who found no association between social orienting and ToM in autistic and

Table 2 Correlations for continuous study variables

Variables	1. SCQ	2. AT	3. SM	4. ToM	5. ER	6. Anx	7. IQ	8. Age	9. CHAOS
2	.82**	–							
3	−.23**	−.21**	–						
4	−.16*	−.24**	−.10	–					
5	−.24**	−.22**	.08	.21**	–				
6	.52**	.65**	−.15	−.08	−.09	–			
7	−.21**	−.22**	−.11	.35**	.14	−.06	–		
8	.08	.10	.02	.24**	−.03	.03	.41**	–	
9	.27**	.33**	−.002	−.06	−.08	.34**	−.11	.003	–

Pearson's *r* reported for parametric variables, Spearman's *p* reported for nonparametric variables.
Age (months); Anx, Anxiety (SCAS Score); AT, Autistic traits (SRS Sum Score); CHAOS Score; ER, Emotion Recognition Accuracy (%); IQ, Verbal IQ Accuracy; SCQ, Social Communication Questionnaire Score; SM, Social Motivation; ToM, Theory of Mind Accuracy.
*$p < .05$; **$p < .001$.

Table 3 Multiple regression testing associations between autistic traits, social motivation, social cognition, and anxiety

Autistic traits (SRS Composite Score)	B^{a}	$SE(B)$	t	p	β^{b}	$F(df)$	p	Adj. R^2
Model 1						12.62 (6,158)	<.001	.30
Social motivation	−.53	0.14	−3.87	<.001	−.26			
Verbal IQ accuracy	−.52	0.12	−3.65	<.001	−.27			
Age	.43	0.13	3.38	<.001	.13			
Sex[c]	−16.52	5.15	−3.34	.003	−.22			
Parental education[d]	−18.45	6.23	−2.97	.003	−.20			
CHAOS	2.94	0.65	4.57	<.001	.30			
Model 1a						10.99 (8, 156)	<.001	.33
Social motivation	−.54	0.14	−3.98	<.001	−.26			
Emotion recognition accuracy	−.28	0.19	−1.34	.15	−.09			
Theory of mind accuracy	−12.42	4.77	−2.37	.01	−.17			
Verbal IQ accuracy	−.40	0.12	−2.77	.002	−.21			
Age	.44	0.13	3.51	.002	.25			
Sex[c]	−13.75	5.06	−2.77	.01	−.19			
Parental education[d]	−18.61	6.38	−3.01	.004	−.20			
CHAOS[e]	2.80	0.66	4.42	<.001	.29			
Model 1b						32.19 (7, 157)	<.001	.57
Social motivation	−.33	0.12	−3.05	.004	−.16			
Anxiety (SCAS[f] Score)	1.04	0.12	10.07	<.001	.56			
Verbal IQ accuracy	−0.46	0.11	−4.09	<.001	−.24			
Age	0.38	0.11	3.83	<.001	.22			
Sex[c]	−18.20	4.26	−4.70	<.001	−.25			
Parental education[d]	−11.03	4.42	−2.25	.01	−.12			
CHAOS[e]	1.20	0.58	2.25	.05	.12			
Model 1c						26.93 (9, 155)	<.001	.59
Social motivation	−0.35	0.12	−3.21	.004	−.17			
Emotion recognition accuracy	−0.18	0.14	−1.11	.20	−.06			
Theory of mind accuracy	−9.83	3.76	−2.39	.01	−.13			
Anxiety (SCAS[f] Score)	1.02	0.12	9.96	<.001	.55			
IQ accuracy	−0.37	0.11	−3.25	.001	−.19			
Age	0.40	0.11	3.99	<.001	.23			
Sex[c]	−16.16	4.02	−4.14	<.001	−.22			
Parental education[d]	−11.17	4.62	−2.28	.02	−.12			
CHAOS[e]	1.15	0.54	2.19	.03	.12			

[a]Unstandardized regression coefficient.
[b]Standardized regression coefficient.
[c]Males coded as 0, females coded as 1.
[d]Degree-educated coded as 1, not degree-educated coded as 0.
[e]Scores on the Confusion, Hubbub and Order Scale.
[f]Spence Child Anxiety Scale.

typically developing preschoolers. Regression analyses showed that controlling for social cognition did not significantly impact the strength of the association between social motivation and autistic traits.

In line with previous studies (Briot et al., 2020; Swain et al., 2015), there was a marginally significant association between social motivation and anxiety (r = −.15, p = .053). [Corrections added on 16 January 2023, after first online publication: In the preceding sentence, 'significant' has been corrected to 'marginally significant' and the r and p values have been added in this version.] Controlling for anxiety in regression analyses significantly reduced the strength of the association between social motivation and autistic traits, suggesting that anxiety traits, which co-occur with autism, account for a significant portion of this association. Controlling for social cognition and anxiety simultaneously yielded results that were similar to controlling for anxiety alone. Given that RRBs have been shown to support self-regulation (Collis, Gavin, Russell, & Brosnan, 2022; Jaffey & Ashwin, 2022), future studies could test the possibility that high social motivation relates indirectly to fewer autism characteristics via reduced demand on RRBs as an anxiety-management strategy.

Social motivation remained significantly associated with autistic traits after controlling for anxiety. Future research is needed to understand whether this residual association is driven by autism itself or by broader co-occurring conditions (e.g. depression). If the latter, this would be consistent with autistic testimonies asserting that reduced social motivation is not a core feature of autism (Jaswal & Akhtar, 2019), as well as evidence from parent interviews indicating the negative impact of reduced social contact during the COVID pandemic for autistic children (Pellicano et al., 2022).

Post hoc analyses split by sex showed that the association between social motivation and autistic traits was significant only in females, as was the attenuating effect of controlling for anxiety. Intense social demands in females' relationships (Sedgewick et al., 2016; Winstead, 1986), or gendered parenting encouraging reciprocal social interactions in females (Johnson, Caskey, Rand, Tucker, & Vohr, 2014; Morawska, 2020), could contribute to these sex-specific effects, allowing females to benefit from greater social motivation, increasing opportunities to build confidence, driving down anxiety compared to equivalent males. Future research may consider whether social motivation and anxiety contribute to the differential presentation of autism in males and females during adolescence (Lai & Szatmari, 2020), where social demands become heightened (Picci & Scherf, 2015).

Sex differences were also present in ToM and CHAOS scores. ToM performance of autistic girls was descriptively similar to the nonautistic boys – similar sex effects have been found for perception of friendships (Head, McGillivray, & Stokes, 2014). CHAOS scores were significantly higher in autistic girls, which could potentially be related to higher co-occurring mental health difficulties on the SDQ and anxiety measures (Angell et al., 2021; Rynkiewicz & Łucka, 2018). Unlike many studies in the autism field (D'Mello, Frosch, Li, Cardinaux, & Gabrieli, 2022), females were well represented in this study. However, this sample overlooks experiences of nonbinary individuals, who are statistically over-represented in the autistic community (Warrier et al., 2020). Proposed sex-linked socialisation processes may not take effect in the same way in nonbinary individuals, possibly reducing the scope of impact for social motivation. Replicating this study in these key groups could provide insight into biological or environmental bases of the effects.

Child age was a predictor of autistic traits when controlling for social motivation and other covariates, although there was no raw correlation. It may be that as children progress through adolescence, social demands begin to exceed capacity to compensate or camouflage autistic traits (Blakemore, 2008; Picci & Scherf, 2015) meaning autistic traits may be more evident in parent-report as children get older.

The current findings emphasise the importance of considering characteristics such as sex and anxiety when seeking to characterise social motivation profiles of autistic youth. From a clinical perspective, given the lack of association between social cognition and social motivation, interventions targeting social cognition are unlikely to directly impact socially motivated behaviours in autism (and vice versa). Instead, interventions should target anxiety management, as well as adaptations to social environments that otherwise fail to accommodate autistic people's needs and preferences (Pellicano & den Houting, 2022).

There are several key strengths of this study including a relatively large sample size with well-characterised youth, scoring across the range of autistic traits. The study used objective, experimental measures to capture key constructs of interest, minimising demands on executive functions that may otherwise have inflated autism-based differences in task performance (Abell et al., 2000; Hedger et al., 2020). The CAM task (Dubey et al., 2015) was adapted in this study to include images of adolescents, rather than adults, therefore maximizing social interest (Knoll, Magis-Weinberg, Speekenbrink, & Blakemore, 2015).

There are also several important limitations to consider. First, as described by Hedge, Powell, and Sumner (2018), condition-based differences in experimental tasks may not be the best way to measure individual differences, although this must be weighed against the advantage of objective measures. Another limitation is that anxiety and autistic trait measures

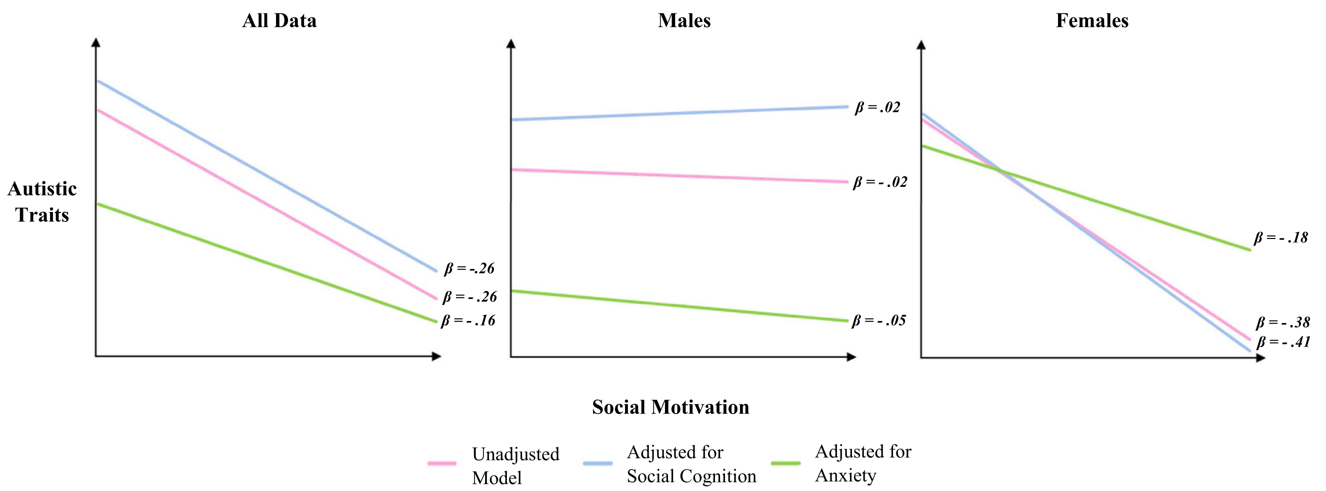

Figure 1 Schematic diagrams illustrating the social motivation-autistic traits associations before and after adjusting for social cognition and anxiety, in all participants, and split by sex. This figure illustrates how the strength of the association between social motivation scores changed when measures of social cognition (theory of mind and emotion recognition) and anxiety, were accounted for. Lines illustrating the social motivation-autistic traits association in each model are labelled with the standardized beta value for social motivation in each regression model predicting autistic traits, with steeper slopes representing a stronger association

Table 4 Descriptive statistics split by sex and diagnostic status

	Males (*N* = 71)			Females (*N* = 94)		
	Autistic (*N* = 37)	Nonautistic (*N* = 34)	Tests of group differences[a]	Autistic (*N* = 33)	Nonautistic (*N* = 61)	Tests of group differences[b]
Variables	Mean (*SD*)		*p*	Mean (*SD*)		*p*
Autistic traits[c]	88.32 (26.39)	46.18 (30.54)	<.001	85.30 (18.07)	36.05 (32.66)	<.001
SCQ total[d]	20.32 (6.79)	8.62 (6.37)	<.001	20.32 (6.79)	8.62 (6.37)	<.001
Age of autism diagnosis (years)	7.49 (3.07)	–	–	9.36 (3.28)	–	–
Social motivation Score (%)	37.72 (17.40)	41.18 (14.81)	.37	32.30 (20.27)	43.66 (17.23)	.008
Average theory of mind accuracy	.66 (.43)	.82 (.49)	.15	.80 (.54)	.96 (.50)	.16
Emotion recognition accuracy (%)	74.13 (10.53)	79.59 (10.86)	.04	76.41 (16.28)	84.35 (9.22)	.01
Anxiety: SCAS total	31.78 (21.07)	25.18 (19.15)	.17	46.39 (16.77)	23.10 (15.90)	<.001
Verbal IQ accuracy	140.32 (21.43)	150.24 (17.84)	.04	148.42 (18.62)	151.10 (17.18)	.50
Verbal IQ *T*-score	144.62 (20.29)	123.74 (18.18)	.05	123.31 (15.22)	118.21 (18.11)	.17
Age (months)	152.45 (20.53)	154.93 (23.73)	.70	164.02 (21.27)	157.41 (18.85)	.13
CHAOS scores[e]	3.62 (3.31)	4.29 (4.08)	.45	6.18 (4.20)	3.87 (3.47)	.01
Parental education[f]	.86 (.35)	.74 (.45)	.17	.79 (.42)	.84 (.37)	.56
SDQ total[a]	18.54 (6.76)	12.94 (10.13)	.01	20.03 (6.21)	9.98 (7.93)	<.001

[a]Total score on the Strengths and Difficulties Questionnaire.
[b]Two-tailed *t*-test (equal variances not assumed) used for continuous variables and chi-square test used for binary variables.
[c]Sum Score calculated by summing raw scores on Restrictive Interests and Repetitive Behaviours, Social Communication, Social Awareness and Social Cognition subscales from the SRS.
[d]Social Communication Questionnaire Total.
[e]Scores on the Confusion, Hubbub and Order Scale.
[f]0 = below undergraduate degree level, 1 = above undergraduate degree level.

were parent-reported and therefore subject to correlated measurement error. Anxiety and autistic traits were highly correlated in our sample, and while this is in keeping with other studies (Maisel et al., 2016; Wigham, Rodgers, South, McConachie, & Freeston, 2015), future research should use teacher report and/or self-report measures. Our study is conducted in a Western, Educated, Industrialized, Rich, and Democratic society, with predominately White (86.7%) participants with degree-educated parents (81.2%). Access to autism services and diagnoses differs by ethnicity (Steinbrenner et al., 2022); autism research must broaden the diversity of participants to ensure findings are generalisable. Our sample also had above average IQ, and the retained versus missing samples differed in VIQ score, potentially because the online delivery of experimental tasks was less suited to participants with below average IQ. Social motivation has been linked to social skills in autistic children across a range of IQs (Itskovich et al., 2021). However, autistic children with higher IQ show increased anxiety, which may be due, in part, to difficulties measuring anxiety in individuals with ID (Mingins, Tarver, Waite, Jones, & Surtees, 2021). Future studies should test whether effects can be replicated across the spectrum of intellectual ability, where the constructs in this study may be challenging to measure. Finally, longitudinal research is needed to test the temporal ordering of the observed cross sectional effects *as they emerge*.

To conclude, this study shows that co-occurring anxiety may contribute to the association between social motivation and autistic traits. Further, differential sex-based analyses suggest that the link between social motivation and autistic traits, and the role of anxiety in this association, is significant only in females. The current findings make a novel contribution to our understanding of the mechanisms underlying autism aetiology and suggest that interventions targeting anxiety may play an important role in supporting social engagement in autism.

Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

Appendices S1-S13 Appendix S1. Full Task Battery.

Appendix S2. Diagnosis and clinical information for autistic sample (*N* = 70).

Appendix S3. Flowchart of participants included in the study.

Appendix S4. Do-Code for Analyses with STATA.

Appendix S5. Table of descriptive statistics split by sex.

Appendix S6. Table of variable ranges by sex and autism diagnostic status.

Appendix S7. Results of multiple regression models including a social motivation – diagnostic status interaction.
Appendix S8. Results of Multiple Regression Analyses by Autism Traits, in males.
Appendix S9. Results of Multiple Regression Analyses by Autism Traits, in females.
Appendix S10. Description of Social Communication Questionnaire (SCQ).
Appendix S11. Results of multiple regression analyses with autistic traits measured by the Social Communication Questionnaire (SCQ) as an outcome.
Appendix S12. Results of multiple regression analyses with autistic traits measured by the Social Communication Questionnaire (SCQ) as an outcome, in males.
Appendix S13. Results of multiple regression analyses with autistic traits measured by the Social Communication Questionnaire (SCQ) as an outcome, in females.

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Data availability statement
Fully anonymised data will be made available on request to the corresponding author.

Endnote

1. We reran all models using the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) as an alternative measure of autistic traits, and the pattern of results remained substantively similar (Appendices S10–S13).

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Key points

- The *Social Motivation Theory* proposes that differences in social reward processing underlie autistic characteristics. However, social motivation has also been linked to anxiety, which co-occurs highly with autism.
- We found that higher social motivation was associated with lower autistic traits; this effect was driven by females.
- Social cognition skills did not explain the association between social motivation and autistic traits. However, controlling for anxiety did significantly reduce the strength of the association, an effect driven by females.
- It may be helpful for interventions in autism to target anxiety management as a potential barrier to engaging in the social environment.

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