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RESEARCH ARTICLE

The role of self-referential and social processing in the relationship between pubertal status and difficulties in mental health and emotion regulation in adolescent girls in the UK

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Abstract

Adolescence is marked by the onset of puberty, which is associated with an increase in mental health difficulties, particularly in girls. Social and self-referential processes also develop during this period: adolescents become more aware of others' perspectives, and judgements about themselves become less favourable. In the current study, data from 119 girls (from London, UK) aged 9–16 years were collected at two-time points (between 2019 and 2021) to investigate the relationship between puberty and difficulties in mental health and emotion regulation, as well as the role of self-referential and social processing in this relationship. Structural equation modelling showed that advanced pubertal status predicted greater mental health and emotion regulation difficulties, including depression and anxiety, rumination and overall difficulties in emotion regulation, and in mental health and behaviour. Advanced pubertal status also predicted greater perspective-taking abilities and negative self-schemas. Exploratory analyses showed that negative self-schemas mediated the relationships between puberty and rumination, overall emotion regulation difficulties, and depression (although these effects were small and would not survive correction for multiple comparisons). The results suggest that advanced pubertal status is associated with higher mental health and emotion regulation problems during adolescence and that negative self-schemas may play a role in this association.

KEYWORDS

emotion regulation, mental health, negative self-schemas, perspective taking, puberty, self-referential processing

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Research Highlights

- This study investigates the relationship between puberty, mental health, emotion regulation difficulties, and social and self-referential processing in girls aged 9–16 years.
- Advanced pubertal status was associated with worse mental health and greater emotion regulation difficulties, better perspective-taking abilities and negative self-schemas.
- Negative self-schemas may play a role in the relationships between advanced pubertal status and depression, and advanced pubertal status and emotion regulation difficulties, including rumination.

1 INTRODUCTION

Mental health difficulties are a leading cause of disability in high- and middle-income countries (Kessler et al., 2007). Internalising symptoms (general low mood and anxiety) are relatively rare before early adolescence (Joinson et al., 2012; Rudolph, 2014), and prevalence rises sharply between 11 and 18 years, with onset often occurring during puberty. Puberty is characterised by increases in sex steroid hormone production and the maturation of reproductive organs, resulting in reproductive capability. In humans, puberty typically begins between 9 and 13 years in females and between 10 and 14 years in males, and is associated with the development of secondary sex characteristics (e.g., male facial hair growth and female breast development) and acceleration in growth (Witchel & Topaloglu, 2019). There is evidence that puberty affects brain development, self-referential, social and emotion processing and mental health (Goddings et al., 2014; Pfeifer & Allen, 2021). However, little is known about how the associations between pubertal status and difficulties in mental health and emotion regulation are related to the development of self-referential and social processing.

Research suggests that, compared with boys, girls are disproportionately vulnerable to the effects of puberty on depression (Bone et al., 2020). Findings from epidemiological studies indicate that rates of depression are similar for girls and boys before puberty onset but, after puberty, rates of depression in girls are approximately twice that of boys (Salk et al., 2017). Analysis of longitudinal data from 9301 individuals showed that, while females and males had similar initial levels of depressive symptoms at age 11, females on average experienced steeper increases in depressive symptoms over their adolescent years until around the age of 20 years, when levels of depressive symptoms plateaued and started to decrease for both females and males (Kwong et al., 2019). A review of studies looking at puberty and the emergence of anxiety symptoms (Reardon et al., 2009) concluded that there is an increased likelihood of symptoms with advancing pubertal status (independent of chronological age) in girls, but not boys. One study using eight waves of data from 630 girls found that depression was associated with early pubertal timing (starting puberty earlier than same-sex peers), but not with age or pubertal status per se (Copeland et al., 2019).

There are likely to be multiple pubertal determinants of risk for mental health difficulties, including direct effects of sex hormones as well as indirect effects, such as the impact on peer relationships, self-identity formation and societal expectations. It has been proposed that focusing on peer relations and social cognition may be critical to understanding the ways in which pubertal development drives neural and psychological changes that produce mental health vulnerabilities in adolescents (Pfeifer & Allen, 2021). Peer interactions and relationships take on heightened importance in adolescence (Tomova et al., 2021) and are a determinant of adaptive psychosocial functioning (Van Harmelen et al., 2017). In turn, being rejected by peers during adolescence is a risk factor for depression and anxiety (Pickering et al., 2020). One study found that self-reported rejection sensitivity, which is higher in girls with more advanced pubertal status, mediated the association between pubertal status and depressive symptoms (Mendle et al., 2020).

The relationship between poor peer relationships, particularly peer victimisation, and poor mental health has been found to be mediated by emotion dysregulation (Mclaughlin et al., 2009). Difficulties in emotion regulation and use of maladaptive emotion regulation strategies such as rumination, which is defined as the tendency to think repetitively about a negative topic (Nolen-Hoeksema, 1991), have been associated with depression and anxiety in adolescent girls and boys (Ahmed et al., 2015). A longitudinal 2-year study of 246 11—14-year-old adolescents found that higher overall difficulties in emotion regulation were more strongly associated with higher depressive symptoms over time in girls than in boys, although this study did not measure puberty (Gonçalves et al., 2019). One cross-sectional study found that girls (but not boys) who started puberty earlier than their peers and who had reached a more advanced stage of puberty demonstrated higher levels of rumination (Mendle et al., 2020). Furthermore, rumination mediated the association between both pubertal status and timing for with depressive symptoms, demonstrating that difficulties in emotion regulation can exacerbate the effects of puberty on mental ill health.

As proposed in Pfeifer and Allen's theoretical model (Pfeifer & Allen, 2021), social cognition, which refers to a complex set of mental abilities that enable us to interpret social information and behave appropriately in a social environment, is key to understanding the relationship between pubertal development and mental health

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vulnerabilities in adolescents. One social cognitive process that continues to improve across adolescence is mentalising, that is, the ability to understand other people's mental states, as evidenced by age-related improvements in the propensity to take another person's perspective, as measured by self-report (Van Der Graaff et al., 2014) and by an experimental perspective taking task (the Director task) (Dumontheil et al., 2010). One study demonstrated that lower mentalising performance was associated with symptoms of withdrawal and/or depression in 89 adolescents aged 12–17 years (Poznyak et al., 2019). It has been proposed that adolescents' improving mentalising abilities might be a critical factor in increased awareness of others' opinions of them. When adolescents take the perspective of their peers or compare themselves to their peers, they judge themselves less favourably (Van Der Aar et al., 2018). In addition, negative self-judgements show an age-related increase across adolescence (Moses-Payne et al., 2022), and there is evidence of a quadratic association between age and later recollection of self-endorsed negative trait adjectives across adolescence (aged 13—20), peaking around age 17 years (Mcarthur et al., 2019). Furthermore, girls, but not boys, in advanced stages of puberty are more likely to view themselves negatively and have worse mental health than girls at earlier stages of puberty (Ke et al., 2018). These negative self-schemas, which can be defined as mental frameworks comprising beliefs about the self that guide attention and memory (Mcarthur et al., 2019), play a role in both the risk and maintenance of depressive symptoms (Friedmann et al., 2016). In a study of 578 participants aged 11–15 years, recall for self-referential negative words was associated with increased depressive symptoms, and this association was stronger in girls (Bone et al., 2021). This suggests that negative self-schemas in self-referential processing might play a role in the association between puberty and mental health.

The research reviewed above highlights the need for a deeper understanding of the association between pubertal development, self-referential processing, social processing and mental health and emotion regulation. The current study investigated the within-person association between pubertal status and three measures of mental health: depression, anxiety and a measure of overall difficulties in mental health and behaviour (Strengths and Difficulties Questionnaire, SDQ (Goodman et al., 1998)). We also investigated the association between pubertal status and two self-reported measures of emotion regulation: rumination and overall difficulties in emotion regulation (Difficulties in Emotion Regulation Scale, DERS (Gratz & Roemer, 2004)). Finally, we investigated the association between pubertal status and three experimental measures of self-referential and social processing: self-schemas in self-referential processing, perspective taking and social rejection sensitivity. The aim was to investigate whether performance on the experimental measures can help explain the relationship between pubertal status, mental health and emotion regulation in girls. We focussed only on girls as, compared with boys, girls show increased vulnerability to internalising mental health problems at puberty (Joinson et al., 2012; Reardon et al., 2009), greater ability to take others' perspectives (Van Der Graaff et al., 2014), more negative self-evaluations (Friedmann et al., 2016) and higher reported rejection sensitivity (Mendle et al., 2020).

This study used a set of two-level structural equation models on data from 119 girls (ages 9–15 years) collected at two time points, approximately 1 year apart. We tested the following within-person hypotheses: advanced pubertal status will be associated with greater mental health and emotion regulation difficulties (Hypothesis 1) and differences in performance on the self-referential and social processing measures (Hypothesis 2); and these associations between advanced pubertal status and greater mental health and emotion regulation difficulties will be mediated by differences in social- and self-referential processing abilities (Hypothesis 3). Finally, we explored whether rumination and overall difficulties in emotion regulation mediated the relationship between pubertal status and the mental health measures (Exploratory Hypothesis 4). Note that our mediation analyses are not used to imply longitudinal mediation, but to compare variance in mental health and emotion regulation outcomes explained by within-person differences in pubertal status and differences in self-referential and social processing between two time points.

2 | METHODS

2.1 | Sample

Participants were recruited from eight schools across London (see Supplemental Information SI1 for sample details and power analyses). The sample included participants who self-identified as girls on a written questionnaire, and who experienced female pubertal changes, as documented by a pubertal development scale, and are referred to as girls throughout. At Time 1, 183 girls (school years 5–9; aged 9.94–15.05 years, M = 13.50, SD = 1.01) were recruited from October 2019 to February 2020 (data collection for 28 Year 5 (of Five) girls was halted due to the COVID-19 pandemic). One hundred twenty-four of these participants returned for Time 2 testing, which took place between October 2020 and March 2021 (school years 6–10; aged 10.81–16.06 years, M = 13.97, SD = 1.02). Five participants were excluded due to missing data for puberty and the mental health and emotion regulation measures. Only participants who took part at both timepoints and who completed the questionnaires were included in the analyses (*N* = 119). Table S1 compares the baseline data of the participants who remained enrolled in the study and participants who dropped out or did not complete Time 2 data collection. The participants who dropped out had significantly higher scores on depression, DERS and SDQ overall difficulties compared to participants who returned for Time 2.

The study was approved by the UCL Research Ethics Committee and carried out in accordance with General Data Protection Regulations (GDPR). Informed consent from parents and assent from all participants was obtained. Participants were compensated with £10 vouchers for taking part in a 1-hour testing session at each timepoint.

2.2 | Pubertal status

Pubertal status was measured using the Pubertal Development Scale (PDS) (Petersen et al., 1988), a self-report measure that assesses five

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TABLE 1 Sample characteristics at Time 1 ($N = 119$).

Sample $N = 119$	Range	Mean	SD	Correlation with pubertal status
Pubertal status	1.2–3.8	2.72	.67	
Age (in years)	9.94–15.05	13.02	1.00	$r(117) = 0.62, p < 0.001$
Non-verbal reasoning	1–9	5.86	1.77	$r(116) = 0.08, p = 0.391$

Note: Pubertal status (scored 1–4), age (in years) and non-verbal reasoning (non-verbal reasoning; scored 0–9), as well as cross-sectional correlations between pubertal status and age, and pubertal status and non-verbal reasoning.

general indicators of development (growth in height, skin changes, growth of body, breast development and menarche), for example: 'Have your breasts begun to grow? 1 = No, 2 = Yes barely, 3 = Yes definitely, 4 = Development completed'. The scores of these five questions were averaged to give a continuous score ranging from 1 (pre-pubertal) to 4 (completed pubertal development; see Supplemental Information SI2 for more details on pubertal status scoring) (Carskadon & Acebo, 1993). No participant reported complete pubertal maturation (a score of 4). At Time 2, 15 participants' puberty scores were lower than their Time 1 score (differences ranging from 0.2 to 0.4, and one participant had a difference of 1). As it is physiologically not feasible to regress through puberty, the Time 1 puberty score was also used for Time 2 for these participants (as opposed to their Time 2 score) to avoid exclusion and the statistical models being driven by implausible biological mechanisms. We also ran a sensitivity analysis using Time 2 scores at both timepoints for these participants (instead of Time 1 scores) to ensure that any results were not driven by the potential overreporting of puberty stage by these participants at Time 1. Age and puberty were correlated in our sample (see Table 1).

2.3 | Non-verbal reasoning

To enable correction for the potential confounding effects of non-verbal reasoning ability on performance in the experimental tasks, participants completed a nine-item abbreviated version of the Raven Standard Progressive Matrices Test, which is a proxy for IQ (Bilker et al., 2012). This measure has previously been used in adolescent samples (Bone et al., 2021). Participants completed the task at both timepoints. As non-verbal reasoning tasks are subject to practice effects, only scores at Time 1 were included in analyses as this was used as a control measure that was assumed to be stable. One participant did not have non-verbal reasoning data at Time 1 due to technical issues. Non-verbal reasoning and pubertal status were not correlated in our sample (see Table 1).

2.4 | Procedure

2.4.1 | Experimental tasks

Participants first completed a series of experimental tasks measuring different self-referential processing and social processing outcomes.

2.4.2 | Self-referential processing task

Task design was based on the paradigm of Moses-Payne et al. (2022). Participants were asked about stimuli that referred to the participants themselves or another female 'familiar other' whom they did not know personally (e.g., celebrity or fictional character). The task consisted of two stages: encoding and retrieval.

Encoding. During encoding, participants were asked to judge how well different words described themselves ('Does this word describe you?') or their chosen other ('Does this word describe [e.g., Hermione Granger]?'), on a 11-point scale from 0 ('Does not describe me/her at all') to 10 ('Totally describes me/her'). Participants judged a total of 64 words based on how well they described themselves (32 words: 18 positive, 14 negative) or their chosen other (32 words: 18 positive, 14 negative).

Retrieval. During retrieval, participants were given a surprise recognition test for words presented in the encoding stage. Participants were tested on all 64 target words seen in the encoding stage (they were asked 'Have you seen this word before?'), alongside 64 distractor words (with the same ratio of positive and negative words; see allocation of words below). Thus, participants made recognition judgements for 128 words in total. Recognition judgements were self-paced, and both the question and word remained on the screen during the judgement.

Allocation of words. Words were generated using the R package LexOPS (Taylor et al., 2020) and were adapted to be understandable for the younger age range, with a maximum age of acquisition at 8.94 (see Table S2). The allocation of words to either target or distractor was pseudo-randomised across participants (for full details, see Supplemental Information SI3), to ensure all participants judged the same number of positive and negative words in each condition (self- vs. other-judged) and at each stage (encoding vs. retrieval).

Calculation of self-schema scores. Two self-schema scores were calculated: a *positive self-schema* score (the proportion of the number of positive words *both* rated as self-descriptive [i.e., rated above 5] and subsequently correctly recognised as proportion of the total number of positive words rated as self-descriptive), and a *negative self-schema score* (derived in the same way using negative words) (Moses-Payne et al., 2022). *Other-schema scores* were calculated this way. *Positive self-schemas* and *other-schemas* were collected to test the robustness of any associations between negative self-schemas and other measures. Eleven participants had missing data at Time 1, four had missing data at Time 2 and three had missing data at both time points.

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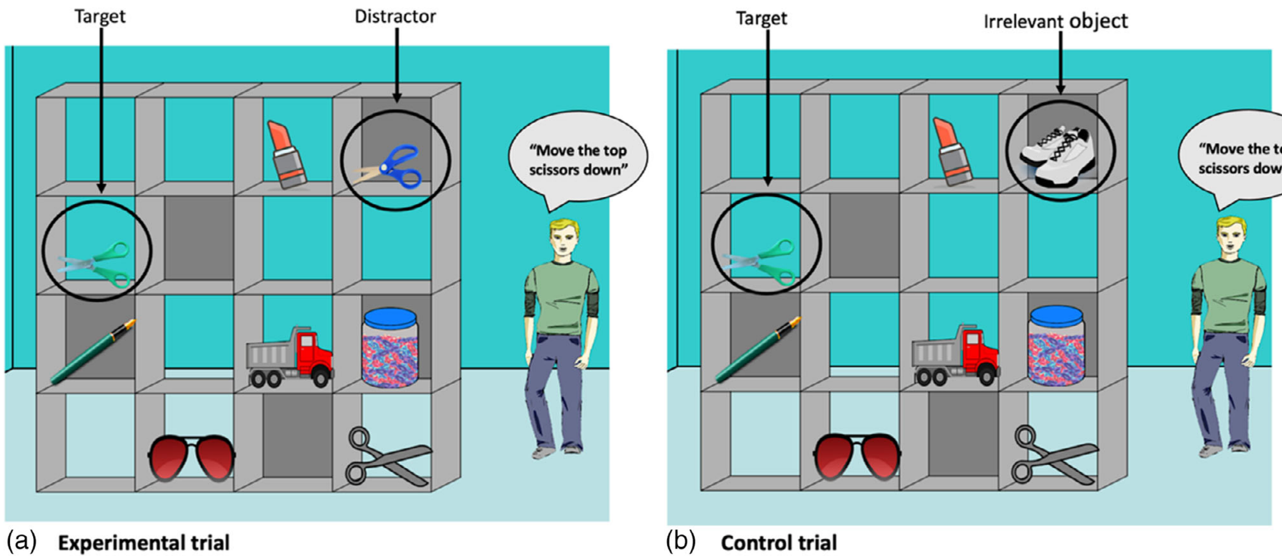

FIGURE 1 Director task example trial. In this example, participants were verbally instructed by the director to 'move the top scissors down'. (a) During experimental trials, an error would be committed when ignoring the director's perspective and incorrectly moving the distractor object, which is not visible to the director. In contrast, a correct response would be to move the target object, which is visible to both director and participant. (b) During control trials, distractor objects were replaced with irrelevant objects (e.g., the trainers).

2.4.3 | Perspective taking—The Director task

The Director task was based on the task designed by Dumontheil et al. (2010), except the object stimuli were replaced with non-copyright versions found using Google Images. The stimuli (48 in total) consisted of sets of 4 × 4 shelves with objects located in eight of the 16 slots. Five of the shelves had an opaque grey background, which occluded the view of the 'director' who stood on the other side of the shelves (i.e., the director viewed the shelves from behind). The director gave verbal instructions to move one of the eight objects to a different slot in the shelves. Before completing the task, participants were presented with an instruction page, which stated that to hear the director's instruction they needed to click the speech button (they could listen to this as many times as they wished) and to remember that they can see objects in the grey slots, but the director cannot. Participants then completed one practice block with three trials and were unable to proceed until they got all three trials correct. The director's instructions were presented via headphones and participants used the computer mouse to move the object they thought the director was referring to into the appropriate slot on the shelves.

During experimental trials (eight in total), a target object could be seen by the participant but not the director (see Figure 1). Participants were instructed to, for example, 'move the top scissors down'. A correct response would consider the director's perspective, and thus the green scissors (target object) would be selected and moved to the appropriate slot. An incorrect response would ignore the director's perspective and move the top-most (blue) scissors (distractor object), which is not visible to the director. In the control trials (eight in total), the object-shelf configurations were identical to those in the experimental trials, except that all relevant objects could be seen by both the participant and the director (see Figure 1). It was therefore not necessary to consider the director's perspective to select the correct answer in these trials. During filler trials (32 in total), instructions only referred to objects in clear slots. For example, in Figure 1 the director could ask to 'move the truck up'. Note that, due to testing time restraints, we did not include the non-social control condition from Dumontheil et al. (2010). The order of the experimental, control and filler trials was counterbalanced between-participants.

Eight different object-shelf configurations were used, each presented once with an occluded distractor object (experimental trial) and once with an irrelevant object (control trial). In total, this resulted in 16 test blocks of different object-shelf configurations, which were all counterbalanced across participants. Three auditory instructions were given per stimulus (i.e., one instruction per trial). The task was self-paced, but participants were told they should complete the task as quickly as possible.

Calculation of perspective taking scores. A *perspective taking* score was coded as the proportion of correct answers out of the total number of trials (8) on the experimental condition of the director task. Two participants had missing data for this task at Time 2.

2.5 | Social rejection sensitivity—Cyberball

Social inclusion and exclusion were simulated using the freeware Cyberball 5.0 program (https://www.empirisoft.com/cyberball.aspx) (Williams & Jarvis, 2006) and embedded into Qualtrics. This program features two virtual players who play an online ball-tossing game with the participant. The participant is led to believe the other animated players are controlled by real people playing the same game over an online connection, when in fact the players are programmed to either include or exclude the participant from the game. The inclusion

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condition generates one third of the ball tosses to the participant whereas the exclusion condition generates only two tosses to the participant at the beginning of the game, after which the other players no longer throw the participant the ball. In each condition, there were 30 throws. Participants completed self-report measures of current mood and feelings of anxiety at baseline (immediately before playing the game) and after both the inclusion and exclusion conditions. There were four items on the mood questionnaire, each rated on a 7-point Likert scale with higher scores indicating better mood. There were six items on the anxiety questionnaire, each rated on a 4-point Likert scale with higher scores indicating greater feelings of anxiety (note some items were recoded). A mean mood and anxiety score was computed at baseline, after inclusion and after exclusion.

Calculation of social rejection sensitivity (anxiety and mood) scores. An *anxiety rejection sensitivity* score was calculated by taking the mean anxiety difference scores between baseline and post-exclusion (post-exclusion mean anxiety—baseline mean anxiety). Therefore, higher difference scores denote higher anxiety rejection sensitivity (i.e., anxiety after exclusion is higher than baseline). A *mood rejection sensitivity* score was calculated by taking the mean mood difference scores between baseline and post-exclusion (baseline mean mood—post-exclusion mean mood). Higher difference scores denote higher mood rejection sensitivity (i.e., mood at baseline is higher than mood after exclusion). Fourteen participants had missing values for anxiety rejection sensitivity and seven for mood rejection sensitivity.

The experimental tasks were presented in the following fixed order: self-referential task (encoding; 7 mins), Director task (5 mins), non-verbal reasoning (4 mins) and self-referential task (retrieval; 10 mins). All experimental tasks were presented using Gorilla (https://gorilla.sc/). These were followed by the questionnaires (see below), delay discounting questions and a friendship quality questionnaire (15 mins; which are not discussed further in this paper), and Cyberball at Time 1 only (7 mins; which was not collected at Time 2 due to the deception element of the task, which participants were later debriefed on), which were presented using Qualtrics (https://qualtrics.com/). The total testing time was 45–60 mins.

2.6 | Mental health and emotion regulation questionnaires

Participants completed a series of questionnaires measuring different mental health and emotion regulation difficulties. We measured three mental health outcomes: *depression* using the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977); *anxiety* using the Revised Children's Anxiety and Depression Scale (RCADS) (Chorpita et al., 2000); and *SDQ total difficulties* using the difficulties subscales of the Strengths and Difficulties Questionnaire (SDQ) (Goodman et al., 1998). We measured two emotion regulation outcomes: *rumination* using the Rumination Response Scale (RRS) (Nolen-Hoeksema, 1991); and *DERS overall difficulties* using the Difficulties in Emotion Regulation Scale (DERS) (Gratz & Roemer, 2004). Higher scores in each measure indicated greater mental health or emotion regulation difficulties (e.g., increased rumination use). All measures were highly correlated with each other, with Pearson correlation coefficients ranging from 0.59 to 0.80 (see Table S3), and all have acceptable or higher ($0.7 \leq \alpha$) internal consistency (see more details on questionnaires in the Supplemental Information SI4).

At Time 1, participants completed the measures in groups (comprising between 2 and 26 participants) at their school, guided by one or two researchers. Participants could not see each other's screens or talk to anyone while taking part. As a result of the COVID-19 pandemic and school closures, data at Time 2 was collected online, either at school ($n = 13$) or at home ($n = 106$).

2.7 | Statistical analysis

The main independent variable of interest was *pubertal status*, and the outcome variables of interest were *rumination*, *DERS overall difficulties*, *depression*, *anxiety* and *SDQ total difficulties*. The measures that were used as mediators were *perspective taking*, *negative self-schema scores*, *anxiety rejection sensitivity* and *mood rejection sensitivity*. We included *positive self-schemas* and *other schemas* (positive and negative) as secondary mediator variables in sensitivity analyses. All variables were coded on continuous scales and were modelled linearly.

Participant-level mean scores were modelled in a set of 2-level structural equation models (SEMs) using *Lavaan* (version 0.6-11) (Rosseel, 2012) in the R environment (version 4.2.3) (Core Team, 2023). An SEM framework allows us to conduct one step mediation analyses on multilevel regressions. Linear regressions were estimated using the *sem* function and were clustered by participant. Level 1 corresponded to within-subject regression estimates and mediations of interest, while level 2 controlled for between-subject fixed effects (i.e., stable aspects of the outcome measures that differ across participants). We used level 1 within participant regression estimates to test our hypotheses. Namely, mental health and emotion regulation difficulties were regressed on pubertal status (Hypothesis 1; see Figure 2 for diagrams); self-referential and social processing were regressed on pubertal status (Hypothesis 2); and mental health and emotion regulation difficulties were regressed on pubertal status and on self-referential and social processing (Hypothesis 3). The latter model (mediation model) uses pathways *a* and *b* (Figure 2) to estimate the indirect effect (IDE) of pubertal status explained by changes in the mediator and pathway *c'* to estimate the remaining direct effect (DE) of pubertal status on the outcome after accounting for the mediator. The sum of the IDE and the DE can be used to calculate the total effect (TE) of pubertal status on the outcome. We used maximum likelihood estimation in conjunction with the delta method to calculate standard errors and assess significance of mediation effects (although this might produce conservative estimates of significance, see Mackinnon et al. (1995)). Hypothesis 1 analyses were corrected for the number of mental health and emotion regulation outcomes and Hypothesis 2 analyses were corrected for the number of self-referential and social processing mediators. As the number of analyses for Hypotheses 3 depended on

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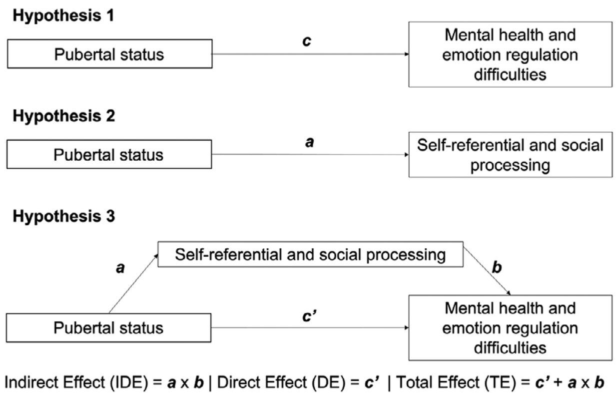

FIGURE 2 Hypotheses: Relationship between pubertal status, mental health and emotion regulation difficulties and self-referential and social processing. Effect of pubertal status on mental health and emotion regulation difficulties (c, Hypothesis 1); effect of pubertal status on self-referential and social processing (a, Hypothesis 2); effect of pubertal status on mental health and emotion regulation difficulties mediated by differences in self-referential and social processing. The product of pathways a and b (a × b) represents the indirect effect explained by the difference in self-referential and social processing (IDE); pathway c' represents the remaining direct effect of pubertal status on mental health and emotion regulation difficulties not explained by the mediator (DE); and the sum of pathways c' and the product of pathways a × b represents the total effect of pubertal status on mental health and emotion regulation difficulties (TE). These effects were estimated within participants, controlling for between-participant fixed effects. Hypotheses 1 and 2 analyses were corrected for alpha-inflation.

the results of the previous analyses, these remained exploratory and were not formally corrected for multiple comparisons.

Social rejection sensitivity (mood and anxiety) data were only collected during Time 1 (due to prior knowledge of the task from Time 1 potentially affecting task outcomes at Time 2) and therefore data were not clustered by participant for these models (i.e. the models only included between-subject fixed effects). Hypotheses for rejection sensitivity were therefore cross-sectional.

Participants with missing data on individual questionnaire items were person-mean imputed if they had more than 50% of the items for the overall measure and were coded as missing otherwise. Missingness on overall measures was accounted for by using full information maximum likelihood estimation. All models were just identified, with the same number of estimated parameters as data points or degrees of freedom akin to simple linear regression models. Considering that traditional SEM model fit indices (e.g., CFI, TLI, RMSEA) are not meaningful in such models, we did not report and interpret model fit. Analysis scripts and de-identified data can be found on the Open Science Framework (https://osf.io/nxaqc/).

2.8 | Exploratory analyses

It has been proposed that difficulties in emotion regulation, including the use of maladaptive emotion regulation strategies, such as rumination, might be precursors to other mental health difficulties (Ahmed et al., 2015; Gonçalves et al., 2019). To investigate the role of emotion regulation difficulties in the relationship between mental health difficulties and pubertal status, we explored whether rumination (see Figure S1 and Table S5) and DERS overall difficulties (see Figure S2 and Table S6) were mediators of the relationship between puberty and mental health difficulties (Exploratory Hypothesis 4). Details of the exploratory analyses can be found in the Supplemental Information.

2.9 | Sensitivity analyses

We ran sensitivity analyses for the main effects and mediation models described above, including relevant covariates in a set of control models (CMs). To enable correction for differences in baseline mental health and emotion processing difficulties and performance on the experimental tasks that are related to chronological age, CM1 included age at Time 1 as a covariate at the between-participant level, as well as the number of months between testing points, which ranged from 7 to 16 months. Including these as between-participant variables allowed us to control for chronological age without running into problems with multicollinearity. In addition, to enable correction for confounding effects of non-verbal abilities on performance on the experimental tasks, CM2 included non-verbal reasoning as a covariate in analyses including experimental measures (perspective taking, self-schemas and rejection sensitivity) at the between-participant level. CM3 included testing group size at Time 1 and CM4 included Time 2 pubertal status scores for participants who reported lower pubertal status at Time 2 than at Time 1 (n = 15). A set of sensitivity analyses on secondary schema variables were conducted to probe the uniqueness of the relationship between pubertal status and negative self-schemas in models including negative self-schemas as a measure. CM5 included positive self-schema scores, CM6 included other positive schema scores and CM7 included other negative schema scores. See details and results of each sensitivity analysis in the Supplemental Information (Tables S7 and S8).

3 | RESULTS

Hypothesis 1. Effect of pubertal status on mental health and emotion regulation difficulties.

The ratings for the mental health and emotion regulation questionnaires are reported in the Supplemental Information. A set of SEMs showed positive relationships between pubertal status and all outcomes of interest: higher rumination (slope = 7.23, SE = 2.02, $p < 0.001$, $p_{adjusted} < 0.001$, $R^2 = 0.10$), DERS overall difficulties (slope = 14.05, SE = 3.66, $p < 0.001$, $p_{adjusted} < 0.001$, $R^2 = 0.11$), depression (slope = 6.68, SE = 1.93, $p = 0.001$, $p_{adjusted} = 0.005$, $R^2 = 0.09$), anxiety (slope = 2.63, SE = 0.96, $p = 0.006$, $p_{adjusted} = 0.030$, $R^2 = 0.06$) and SDQ total difficulties (slope = 2.10, SE = 0.76, $p = 0.006$, $p_{adjusted} = 0.030$, $R^2 = 0.06$) were associated with within-participant

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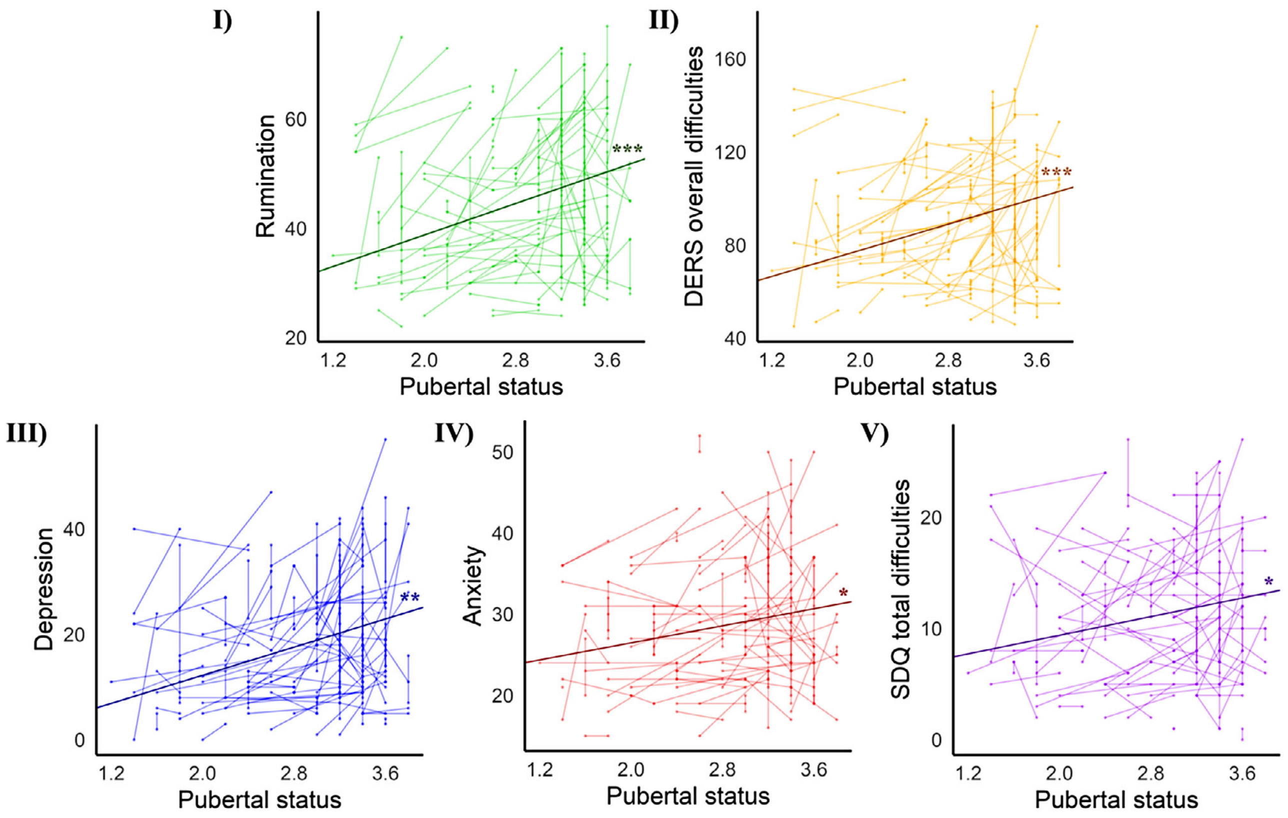

FIGURE 3 Within-participant relationship between mental health and emotion regulation difficulties and pubertal status. The plots show rumination, DERS overall difficulties, depression, anxiety and SDQ total difficulties as a function of pubertal status. Dots and lines represent participant-level descriptive statistics of mental health and emotion regulation difficulties at Time 1 to Time 2. Lines of best fit represent mean within-participant differences in mental health and emotion regulation difficulties related to advanced pubertal status, controlling for between-participant fixed effects, as estimated by the structural equation models. Asterisks show corrected significance levels. $^{***}p_{\text{adjusted}} < 0.001$, $^{**}p_{\text{adjusted}} < 0.01$, $^{*}p_{\text{adjusted}} < 0.05$.

advanced pubertal status. All effects were statistically significant after adjusting for multiple comparisons. See Figure 3 for within-participant mental health and emotion regulation difficulties and pubertal status at Time 1 and Time 2.

Hypothesis 2. Effect of pubertal status on self-referential and social processing.

The results of the experimental tasks and their descriptive statistics are reported in Table 2. In summary, accuracy in the experimental condition of the Director task (perspective taking) improved across timepoints: 53% at Time 1 and 62% at Time 2, which were both significantly lower than the accuracy in the control conditions. In the self-referential task, participants remembered a significantly higher number of self-descriptive words (negative and positive) in comparison to words descriptive of another person both at Time 1 and Time 2. In the Cyberball task, mood was significantly reduced after exclusion compared with baseline and after inclusion, whereas state anxiety was greater after exclusion compared with baseline or after inclusion.

A set of SEMs showed positive relationships between puberty and perspective taking and negative self-schemas. Specifically, better performance on the perspective taking task (slope = 0.15, SE = 0.06, p = 0.016, p_{adjusted} = 0.064, R^2 = 0.05) and higher negative self-schemas (slope = 0.06, SE = 0.02, p = 0.006, p_{adjusted} = 0.024, R^2 = 0.07) were associated with within-participant advanced pubertal status. Note, however, that the effect of puberty on perspective taking was not statistically significant after adjusting for multiple comparisons. There was no significant association between puberty and mood, or between puberty and anxiety, following social exclusion in the Cyberball task (mood rejection sensitivity: slope = −0.05, SE = 0.14, p = 0.745, R^2 = 0; anxiety rejection sensitivity: slope = 0.04, SE = 0.06, p = 0.526, R^2 = 0). See Figure 4 for within-participant perspective taking, negative self-schemas and pubertal status at Time 1 and Time 2, as well as rejection sensitivity (mood and anxiety) and pubertal status at Time 1. Sensitivity analyses on secondary schema variables found no significant relationship between puberty and positive self-schemas (slope = −0.04, SE = 0.04, p = 0.336, R^2 = 0.01), puberty and positive other-schemas (slope = −0.05, SE = 0.03, p = 0.172, R^2 = 0.02), and puberty and negative other-schemas (slope = −0.03, SE = 0.02, p = 0.169, R^2 = 0.02).

Hypothesis 3. Mediation of self-referential and social processing on the relationship between pubertal status and mental health and emotion regulation difficulties.

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TABLE 2 Descriptive statistics for experimental tasks.

	N	Mean	SD	Min	Max	Paired *t*-tests
Time 1						
Perspective Taking (proportion correct)						
Experimental condition	119	0.53	0.31	0	1	$t(118) = -15.37, p < 0.001$
Control condition	119	0.96	0.07	0.63	1	
Negative Schemas (proportion recalled)						
Self-schemas	105	0.24	0.14	0	0.61	$t(104) = 4.74, p < 0.001$
Other schemas	105	0.16	0.12	0	0.56	
Rejection Sensitivity (state anxiety)						
Baseline	112	1.78	0.56	1	3.67	$t(104) = -4.09, p < 0.001$
Inclusion	110	1.76	0.59	1	3.67	$t(104) = -5.14, p < 0.001$
Exclusion	105	1.93	0.67	1	3.83	
Rejection Sensitivity (mood)						
Baseline	113	5.47	1.13	2.25	7	$t(111) = 8.96, p < 0.001$
Inclusion	112	5.43	1.20	2.50	7	$t(111) = 9.55, p < 0.001$
Exclusion	112	4.62	1.50	1	7	
Positive Schemas (proportion recalled)						
Self-schemas	105	0.64	0.18	0.11	0.94	$t(104) = 4.38, p < 0.001$
Other schemas	105	0.55	0.18	0.06	1	
Time 2						
Perspective Taking (proportion correct)						
Experimental condition	117	0.62	0.33	0	1	$t(116) = -12.03, p < 0.001$
Control condition	117	0.98	0.06	0.75	1	
Negative Schemas (proportion recalled)						
Self-schemas	112	0.27	0.14	0	0.78	$t(111) = 7.96, p < 0.001$
Other schemas	112	0.15	0.09	0	0.39	
Positive Schemas (proportion recalled)						
Self-schemas	112	0.61	0.20	0.11	0.94	$t(111) = 5.27, p < 0.001$
Other schemas	112	0.50	0.16	0.11	0.83	

Note: Descriptive statistics for accuracy in the experimental and control conditions of the Director task at Time 1 and Time 2; the proportion of recalled words in the self and other conditions of the self-referential task (positive and negative schemas) at Time 1 and Time 2; and mood and anxiety scores at baseline, after inclusion and after exclusion during the Cyberball task at Time 1. The paired *t*-tests column shows the difference between the conditions in the director task, between self and other conditions in the self-reference task, and between baseline and exclusion and inclusion and exclusion in the Cyberball task.

A set of mediation analyses including perspective taking abilities as a mediator of the relationship between pubertal status and the mental health and emotion regulation difficulties showed that better performance on the perspective taking task did not significantly mediate the relationship between pubertal status and any of the outcomes in our analyses (all IDE $ps \geq 0.117$; see Figure S3 and Table S9).

A second set of mediation analyses showed that negative self-schema scores mediated the relationship between pubertal status and rumination, pubertal status and DERS overall difficulties, as well as between pubertal status and depression (see Table 3; see mediation diagrams in Figure 5). Specifically, negative self-schemas had a positive indirect effect on rumination (IDE = 1.94, SE = 0.88, $p = 0.028$), DERS overall difficulties (IDE = 3.76, SE = 1.67, $p = 0.025$) and depression (IDE = 2.00, SE = 0.88, $p = 0.023$). This suggests that the relationship between pubertal status and higher rumination, DERS overall difficulties and depression was at least partially mediated by within-participant differences in negative self-schemas in our data. These indirect effects would not survive formal adjustments for multiple comparisons. Negative self-schemas did not significantly mediate the relationship between pubertal status and anxiety or SDQ total difficulties (see Table 3; see mediation diagrams in Figure 5).

Given that pubertal status did not have a main effect on rejection sensitivity (mood and anxiety), no mediation analyses were conducted using rejection sensitivity as a mediator of puberty and the outcome measures.

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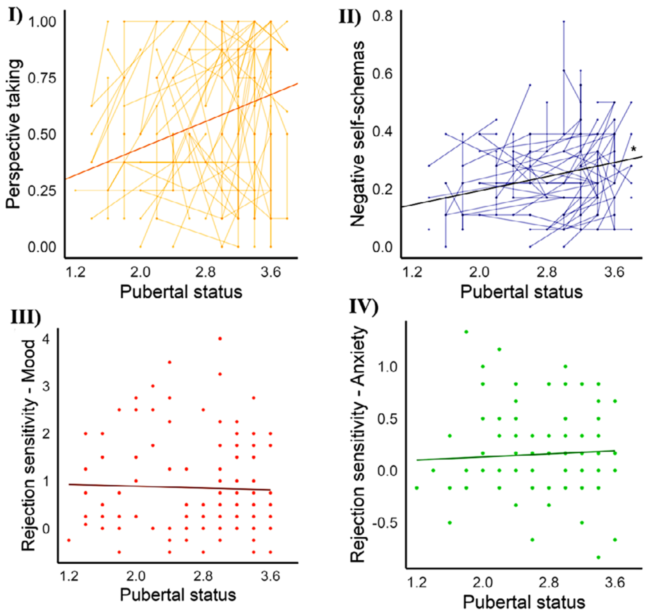

FIGURE 4 Within-participant relationship between self-referential and social processing measures and pubertal status. The plots show perspective taking (percentage of correct answers in the Director task), negative self-schemas (proportion of recalled self-descriptive words compared to total self-descriptive words measured in the self-referential task), mood rejection sensitivity (difference in feelings of mood after exclusion compared to baseline; baseline—exclusion) and anxiety rejection sensitivity (difference in anxiety after exclusion compared to baseline; exclusion—baseline) as a function of pubertal status. (Top) Dots and lines represent participant-level descriptive statistics of perspective taking (I) and negative self-schemas (II) at Time 1 to Time 2. Lines of best fit represent mean within-participant differences in perspective taking and negative self-schemas related to advanced pubertal status, controlling for between-participant fixed effects, as estimated by the structural equation models. (Bottom) Dots represent participant-level mood rejection sensitivity (III) and anxiety rejection sensitivity (IV) at Time 1. The line of best fit represents mean between-participant mood and anxiety rejection sensitivity by pubertal status, as estimated by the structural equation models. Asterisks show corrected significance levels. $^{*}p_{\text{adjusted}} < 0.05$.

3.1 | Sensitivity analyses

To probe the robustness of our findings, we ran a set of sensitivity analyses for each model including additional covariates. All models reported in this manuscript were robust to the inclusion of one of the following covariates: participant age at Time 1 and time between Time 1 and Time 2 (CM1); testing group size at Time 1 (CM3); and Time 2 pubertal status scores for participants who reported lower pubertal status at Time 2 than at Time 1 ($n = 15$; CM4). The relationship between puberty and the experimental measures was additionally robust to participant non-verbal reasoning at Time 1 (CM2). Finally, the relationship between puberty and negative self-schemas, as well as the mediation of negative self-schemas on the relationship between puberty and mental health and emotion regulation difficulties, was robust to positive self-schemas (CM5), positive other schemas (CM6) and negative other schemas (CM7). See details and results of each sensitivity analysis in the Supplemental Information (Tables S7 and S8).

TABLE 3 Relationship between pubertal status and mental health and emotion regulation difficulties mediated by negative self-schemas.

Outcome	Estimate	SE	*p* value	Estimate (std)
Rumination				
IDE	1.94	0.88	0.028	0.08
DE	5.29	2.01	0.009	0.23
TE	7.23	2.02	<0.001	0.31
DERS overall difficulties				
IDE	3.76	1.67	0.025	0.09
DE	10.78	3.56	0.002	0.26
TE	14.54	3.66	<0.001	0.35
Depression				
IDE	2.00	0.88	0.023	0.09
DE	4.76	1.90	0.012	0.22
TE	6.76	1.92	<0.001	0.31
Anxiety				
IDE	0.46	0.32	0.151	0.04
DE	2.24	0.98	0.022	0.21
TE	2.70	0.96	0.005	0.26
SDQ total difficulties				
IDE	0.49	0.27	0.069	0.06
DE	1.63	0.77	0.033	0.19
TE	2.12	0.76	0.005	0.25

Note: The table shows the unstandardised and standardised (std) estimates and standard errors (SE) of the Indirect Effect (IDE), Direct Effect (DE), and Total Effect (TE) of pubertal status on the different mental health and emotion regulation difficulties, after accounting for negative self-schemas. These effects are estimated within participants, controlling for between-participant fixed effects.

4 | DISCUSSION

The current study investigated the role of self-referential and social processing in the relationship between pubertal status and mental health and emotion regulation difficulties in girls aged 9–16 years, who were tested at two time points approximately 1 year apart. The results showed that within-person advanced pubertal status was associated with higher mental health and emotion regulation difficulties, better perspective taking and higher negative self-schemas. Furthermore, mediation analyses suggested that negative self-schemas, but not perspective taking, may have an indirect effect on the relationship between puberty and rumination, puberty and overall emotion regulation difficulties, as well as puberty and depression.

In support of our first hypothesis, depression, anxiety, rumination, overall difficulties in emotion regulation (DERS) and overall difficulties in mental health and behaviour (SDQ total difficulties) were higher

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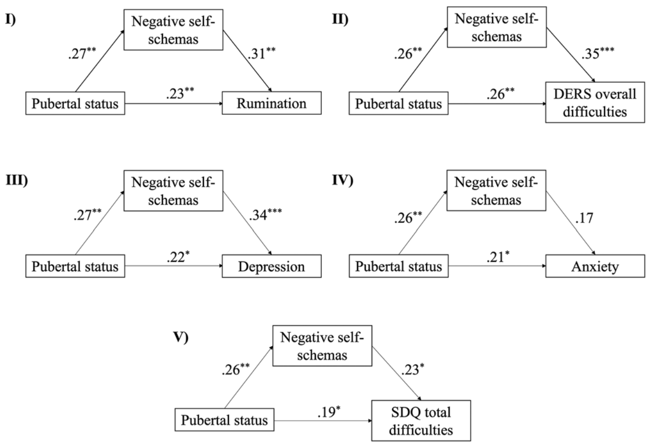

FIGURE 5 Mediation diagrams showing the relationship between pubertal status and mental health and emotion regulation difficulties after accounting for negative self-schemas. Standardised effects of (pathway a) pubertal status on negative self-schemas; (pathway b) negative self-schemas on mental health and emotion regulation difficulties; as well as (pathway c') the remaining direct effect of pubertal status on mental health and emotion regulation difficulties after accounting for negative-self-schemas as estimated by the exploratory structural equation models. These effects are estimated within participants, controlling for between-participant fixed effects. Diagram (IV) shows significant effects in pathways a and c', but not pathway b. All other diagrams show significant effects in pathways a, b and c'. Asterisks show uncorrected significance levels. $^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$.

with more advanced pubertal status. This is in line with previous cross-sectional and longitudinal studies showing that more advanced pubertal status is associated with higher levels of anxiety (Reardon et al., 2009), rumination (Mendle et al., 2020) and depression (Joinson et al., 2012). These results are also in line with several theories regarding the effect of puberty on risk for mental health problems in girls, which are centred around early (or atypical) timing and tempo of puberty, such as maturational compression (faster progression than peers) and developmental readiness (developmental gap between biological and cognitive, emotional and social maturity; see Witchel and Topaloglu (2019) for review).

The structural equation models showed mixed results for our second hypothesis investigating the relationship between advanced pubertal status and differences in self-referential and social processing. More advanced pubertal status was associated with better perspective taking and higher negative self-schemas. This extends previous evidence that social cognition, such as mentalising, continues to improve throughout adolescence and into adulthood by demonstrating that perspective taking also improves across puberty (Poznyak et al., 2019; Van Der Graaff et al., 2014). This main effect further expands this literature by suggesting that puberty could be related to improvements in perspective taking in girls (although it should be noted these effects were small and did not survive formal adjustment for multiple comparisons). It is also important to note that we did not include the non-social control condition of the Director task due to time constraints and therefore we cannot infer that differences are purely social in nature.

We also found that negative self-schemas, defined here as a combination of encoding negative self-descriptions and later recognising them, were positively associated with pubertal status in adolescent girls. Specifically, our results showed that within-participant advanced pubertal status was associated with higher negative self-schemas. These findings are consistent with studies investigating self-referential judgements, which suggest that there is an age-related increase in negative self-judgements across adolescence, and a reduced positive bias in memory for self- and other-referential trait adjectives in early adolescence (McArthur et al., 2019). In addition, pubertal status did not significantly predict positive self-schemas, or positive and negative schemas of other individuals. This suggests that pubertal status might be related to how adolescents use self-relevant information specifically to make negative judgements about themselves and how likely they are to later remember these negative self-judgements.

Belonging is of particular importance in adolescence, with young people being especially sensitive to social rejection (Tomova et al., 2021). In the current study, we hypothesised that pubertal status might explain differences in rejection sensitivity. We found that, while negative mood and anxiety increased after being socially excluded in the Cyberball task, as has previously been reported (Sebastian et al., 2010), this sensitivity to exclusion was not significantly associated with pubertal status. This could be related to the paradigm used in this study, which entails excluding the participant from an online ball throwing game. Two other studies using different measures of rejection sensitivity, self-report (Mendle et al., 2020) and an online chatroom interaction paradigm (Silk et al., 2014), found that advanced pubertal status was cross-sectionally related to increased rejection sensitivity, and that both these measures of rejection sensitivity mediated differences in depressive symptoms in adolescent girls. Future research could use more ecologically valid online and in-person paradigms, such as the chatroom task (Silk et al., 2014), to elucidate the relationship between pubertal development and sensitivity to peer rejection.

Our third hypothesis proposed that greater mental health and emotion regulation difficulties associated with advanced puberty might be explained by differences in self-referential and social processing abilities. We found that higher negative self-schemas, but not perspective taking, mediated the relationship between advanced pubertal status and three outcomes of interest. Specifically, higher within-participant negative self-schemas associated with advanced pubertal status at least partially explained the effect of advanced puberty on higher rumination, DERS overall difficulties and depression. Within-participant differences in negative self-schemas did not explain the relationship between advanced pubertal status and anxiety or SDQ total difficulties. While these effects are small and would not survive formal adjustment for multiple comparisons, the results extend previous findings showing heightened mental health disorders in girls at later stages of puberty (Salk et al., 2017) by suggesting that increased memory of negative self-judgements might be a potential mechanism involved in the relationship between emotion regulation difficulties and depression.

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There are several potential explanations for the relationship between puberty, negative self-schemas and higher difficulties in emotion regulation and depression. First, there could be direct effects of pubertal hormones. There is evidence that the increase in depression in females during adolescence is related to oestrogen levels (Joinson et al., 2012). Oestrogen can affect sensitivity of the socio-affective neural circuitry that underlies the processing and encoding of emotional information (Albert & Newhouse, 2019), which might influence performance on emotion processing tasks such as the self-referential task used in the current study (Goddings et al., 2012). Sensitivity to socio-affective information could influence the salience of social evaluation and feelings of self-consciousness, which are related to internalising symptoms, such as depression and stress (Hankin et al., 2010; Somerville et al., 2013).

A second explanation involves the indirect effects that pubertal development has on young people's experiences. For example, puberty leads to changes in physical appearance, such as increases in body fat and breast development in girls (Rudolph, 2014). Such changes could influence the endorsement of more negative views of oneself (Schaffhuser et al., 2017). Coupled with adolescents' increased use of peer social comparisons and social norms to inform views about themselves (Van Der Aar et al., 2018), negative social comparisons based on physical appearance are associated with depression symptoms and decreased self-esteem, particularly in Western cultures (Hamlat et al., 2015). Similarly, pubertal development in girls leads to changes in societal expectations and the adoption of new societal roles. Gender norms become more salient with pubertal development (gender intensification) (Bone et al., 2020; Barrett & White, 2002), with girls being more likely to be sexualised (Zurbriggen et al., 2007) and 'adultified' (perceived as older and less innocent) (Mendle & Koch, 2019), than before puberty. Gender intensification can translate to increased pressures to meet heightened expectations in the academic and social domains (Schaffhuser et al., 2017). These changes can lead to negative feelings of inadequacy, depressive symptoms and use of maladaptive emotion regulation strategies, such as rumination or silencing behaviours (McLean et al., 2014; Zurbriggen et al., 2007).

Finally, the effect of pubertal status on negative self-schemas and depression could be related to the emergence of maladaptive emotional coping strategies, such as rumination. The availability of more negative self-judgements in an adolescent's self-schema might increase the likelihood of repetitively thinking about those negative attributes (i.e., rumination) (Nolen-Hoeksema, 1991). This can be thought of as a difficulty in emotion regulation, which has been proposed to contribute to internalising problems (Mclaughlin et al., 2009), including depression and anxiety (Ahmed et al., 2015; Young et al., 2019). In line with this, our exploratory analyses showed that the relationship between advanced pubertal status and depression, anxiety and SDQ total difficulties was explained by DERS overall difficulties and, more specifically, rumination. Thus, maladaptive emotion regulation strategies such as rumination, as well as other maladaptive strategies such as self-blame or denial (Ahmed et al., 2015) that are yet to be directly investigated in this context, could play a role in the relationship between puberty, self-schemas and mental health difficulties (McLean et al., 2014). Alternatively, although we have primarily focussed on how the development of negative self-schemas could affect mental health and emotion regulation, it remains plausible that there is a bi-directional relationship between negative self-schemas and depressive symptoms and rumination. As such, the emergence of depressive symptoms may also impact how negative self-relevant information is encoded into memory (Disner et al., 2017) and engaging in rumination on negative self-imagery may promote its consolidation to memory (Moulds et al., 2007). The current study was underpowered to detect small effects that would be robust to comparisons in more complex mediation models, for example, serial mediation models including self-referential, social and emotional processes as mediators. Future research should aim to understand how difficulties in emotion regulation strategies related to pubertal development, such as rumination, interact with self-referential and social processes that become more sophisticated during adolescence, and together might comprise mechanisms by which mental health problems become more prevalent during this period.

4.1 | Limitations

There are several limitations of the current study. First, this study was interrupted by the outbreak of the COVID-19 pandemic. Consequently, data collection at Time 1 was halted before collecting data from the younger sample, resulting in a lower proportion of girls in early puberty and thus a lack of pubertal variation to explore pubertal timing. Furthermore, due to school closures, data collection at Time 2 occurred entirely online and resulted in an increased dropout rate ($n = 59$). While there are potential confounding effects of school closures and consequential online testing at Time 2 (vs. in-person testing at Time 1), this was the case for all participants and therefore this is unlikely to impact the interactions with puberty. However, studies have shown significant changes in mental health symptoms of adolescents during the initial months of the pandemic (Barendse et al., 2023; Racine et al., 2021) and this may have had an impact on the reported mental health of our sample. Indeed, depression scores reaching the at-risk cut-off increased from 43.7% at Time 1 to 60.2% at Time 2 (see Table S4). This is despite the fact that a number of participants did not return at Time 2 and those who dropped out had significantly higher scores on depression, DERS overall difficulties and SDQ total difficulties compared to participants who returned at Time 2 (see Table S1). The results should therefore be interpreted in light of these potential cohort effects and future research is needed to replicate these findings outside of a global pandemic.

A second limitation is that puberty and age showed a high correlation between-participants at both time points in our study ($r = 0.62$ at Time 1 and $r = 0.65$ at Time 2). Conceptually, *age* is a combination of several processes that develop with time (including pubertal development), and therefore puberty and age are usually highly correlated. This collinearity makes it difficult to disentangle their separate influences on developmental processes in statistical models (Cheng et al., 2021). In this study, we used a set of sensitivity analyses to control for

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between-participant chronological age, which did not show differences in within-participant puberty-related effects. Pubertal development is complex and multifactorial: our study focussed on associations with pubertal status (what stage of pubertal development an individual is in) rather than pubertal timing (an individual's pubertal development in relation to their peers), pubertal tempo (rate of change related to different pubertal processes) or age of onset (including thelarche, gonadarche, menarche, spermarche), as our study was not optimised to explore this in detail. In addition, while the PDS is the most frequently used puberty assessment tool in research studies and has moderate-good correlations with physician assessment of pubertal status, some limitations have been described by other authors (see e.g., Cheng et al. 2021). For example, younger participants are more likely to over-estimate their pubertal status while older participants are more likely to under-estimate their pubertal status. Some processes (e.g., changes in height) are not continuous throughout puberty and this can influence self-reported responses and can occasionally indicate apparent pubertal regression (which is not physiologically feasible in reality). Including additional hormonal measures of pubertal status might provide insight into our findings (Silk et al., 2014). Future research could explore designs using larger samples with a narrower age range to disentangle the longitudinal role of different pubertal development measures from each other and from chronological age in development and mental health. Such designs would better control for confounding between-person influences in interpreting developmental data (Hamaker et al., 2015).

5 | CONCLUSION

The results of the current study suggest that negative self-schemas may play a role in the effect of pubertal status on depression and emotion regulation difficulties in girls. Integrating school programmes that focus on physical, psychological and emotional changes related to pubertal development could help deconstruct negative stereotypes about the changes that occur during this critical period of life (Barkhordari-Sharifabad et al., 2020). In addition, school-based interventions could be designed to improve how girls process self-relevant emotional information, for example, affective cognitive control training (the ability to regulate emotions or to manipulate them in the service of task goals) (Schweizer et al., 2013). Such programmes could help reduce psychological vulnerabilities that young girls face during adolescence.

AUTHOR CONTRIBUTIONS

Saz P. Ahmed, Madeleine E. Moses-Payne and Sarah-Jayne Blakemore participated in the design of the study; Saz P. Ahmed, Blanca Piera Pi-Sunyer, Madeleine E. Moses-Payne organised testing and collected data; Blanca Piera Pi-Sunyer, Saz P. Ahmed, Madeleine E. Moses-Payne and Lydia G. Speyer participated in the analysis of the data; all authors participated in the interpretation of the data, as well as in drafting and revising the manuscript, and have approved the submitted version.

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ETHICS STATEMENT

The study was approved by the UCL Research Ethics Committee and carried out in accordance with General Data Protection Regulations (GDPR).

CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests. Declarations of interest are regularly updated on the Blakemore Lab website (https://sites.google.com/site/blakemorelab).

DATA AVAILABILITY STATEMENT

The analysis scripts and de-identified data used in this study can be found in the Open Science Framework (https://osf.io/nxaqc/).

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